NAWCWPNS TP 8270

Data Analysis of High Temperature Superconductive Spiral's Antenna Chamber Patterns

by
Michael M. Neel
G & C Systems Division

DECEMBER 1995

NAVAL AIR WARFARE CENTER WEAPONS DIVISION
CHINA LAKE, CA 93555-6001

Approved for public release; distribution unlimited.

Naval Air Warfare Center Weapons Division

FOREWORD

This report presents analysis of data taken at the American Electronic Laboratory Industries facility in Lansdale, PA, on High Temperature Superconductor Spiral Antennas constructed under contract for the Office of Naval Research.

This work was performed at the Naval Air Warfare Center Weapons Division, China Lake, CA during fiscal year 1994 in support of an Accelerated Technology Initiative investigating High Temperature Superconducting Antennas sponsored by the Office of Naval Research, Information, Electronics and Surveillance Science and Technology Department (ONR 31). This work was monitored initially by Dr. Y. S. Park and supsequently by Dr. Deborah Van Vechten under fund document N0001494WX35177.

This report is a working document subject to change and was reviewed for technical accuracy by Donald R. Bowling.

Approved by
K. L. HIGGINS, *Head*
G & C Systems Division
20 December 1995

Under authority of
D. B. McKINNEY
RAdm., U.S. Navy
Commander

Released for publication by
S. HAALAND
Director for Research and Engineering

NAWCWPNS Technical Publication 8270

Published by . . . . Scientific Technical Documentation
Collation . . . . Cover, 31 leaves
First printing . . . . 45 copies

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
December 1995

3. REPORT TYPE AND DATES COVERED
February 1994-June 1995

4. TITLE AND SUBTITLE
Data Analysis of High Temperature Superconductive Spiral's Antenna Chamber Patterns

5. FUNDING NUMBERS
N00014-94-WX-35177

6. AUTHOR(S)
Michael M. Neel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Air Warfare Center Weapons Division
China Lake, CA 93555-6001

8. PERFORMING ORGANIZATION REPORT NUMBER
NAWCWPNS TP 8270

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Dr. Deborah Van Vechten
Office of Naval Research
Code 312, BCT1 607
800 North Quincy Street
Arlington, VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12A. DISTRIBUTION/AVAILABILITY STATEMENT
A Statement; public release; distribution unlimited.

12B. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

(U) This report presents analysis of data taken by American Electronic Laboratory Industries on High Temperature Superconductive Spirals built under contract for the Office of Naval Research.

14. SUBJECT TERMS
Antenna
Sprial
High Temperature Superconductor

15. NUMBER OF PAGES
61

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT
UL

ANALYSIS OF AMERICAN ELECTRONIC LABORATORY (AEL) INDUSTRIES, INC. HTS SPIRAL TEST DATA

In February 1995, AEL Industries completed the testing of high temperature superconductive (HTS) spirals built for the Office of Naval Research (ONR) (Reference 1). The test plan, developed jointly by AEL Industries and the Naval Air Warfare Center Weapons Division during the planning stages of the contract, was intended to supply enough data to give a thorough indication of the HTS spirals performance over low frequencies. The test plan and basic explanation of the results are found in the final report supplied by AEL Industries.

This report will address those test results in more detail. The performance improvements and problems will be discussed, with an emphasis on looking at how these would apply in practical use. Pictures of the hardware as supplied are in Appendix A.

UNTERMINATED SPIRAL RESULTS

For the dates of 15 November to 3 December 1994, the tests were done with the spiral arms unterminated with any resistors. The reason for this was to obtain a baseline set of data which would highlight the effects of essentially zero conductor loss. Testing with this configuration provides a rough idea of the pattern shapes and indicates the frequency transition where the spiral will begin to change from an electrically small antenna. The polar antenna pattern plots of these data are contained in Appendix B.

For the tests performed on these dates, these data was taken as amplitude only, referenced to a gain calibrated antenna (making all patterns calibrated to dB isotropic). The tests were done in sets of three conditions, one with the source antenna set to vertical polarization, one with it set to horizontal polarization, and one with the source antenna rotating during the test. Because these was amplitude only, the rotating linear transmitting source data is the only fully informative data set. This data set encompasses the response of the antenna to all senses of source polarization.

Data was taken on two 2-inch HTS, one 2-inch gold, two 3-inch HTS, and one 3-inch gold spirals. These data on the gold spirals is the "reference" data set, hopefully indicating the best attainable performance with normal metal spiral arms. The tests on 3 and 9 December had no data on the #2, 2-inch HTS antenna because of a defect that caused its failure. These tests were done from 0.25 to 2 GHz. The tests on the 2-inch spirals were also performed from 2 to 20 GHz. This analysis will be limited to the tests from 0.25 to 2 GHz.

These data on the 3-inch spirals indicate the general tendency of the antenna gain to drop as the frequency goes lower. The comparative gains between the gold and HTS spirals was as expected, which showed the gain of the HTS spiral to be about 6 dB higher than the gold spiral above 0.7 GHz, and about 10-15 dB higher than the gold spiral below 0.7 Ghz. The notable change across the frequency band was in the "axial ratio." This is defined as the decibel difference between the antenna's maximum and minimum gain response to a full 180 degrees of source polarization change. In these tests, this change is noted as the source is rotated. This is essentially the maximum and minimum of the antenna's polarization ellipse. The lower this axial ratio, the better quality the antenna's circular polarization is.

In the patterns taken, the axial ratio of the HTS spiral is noted to remain consistently between 2 and 4 dB above 1.1 GHz. Below 1.1 GHz, the axial ratio goes as high as 15 dB, which indicates a highly linear response. This is consistent with the expected result. With no arm terminations, the power flow down the spiral arms will reflect at the ends. If the power radiated is low, this reflected power will result in a significant standing wave interaction on the spiral arms, which results in degradation of the spiral's circular polarization. For a 3-inch diameter spiral, the radiated power should begin to drop off as the frequency falls below 1.2 GHz.

The absolute gain levels for these tests were not looked at too closely, due to this interaction. The reflected power off the arm ends could cause either an apparent gain increase or decrease, depending on frequency. Thus, only general pattern tendencies were examined.

The pattern shapes of the HTS spirals tended to be better quality below 1.1 GHz than the gold spirals. At the extreme low end (0.25 to 0.4 GHz), the pattern quality was hard to assess, due to the fact that the gold antenna's response was below the receiver noise floor. Over this frequency range, the pattern quality was fairly poor. This is expected for a spiral without terminations on the arms. The general comment on this set of data is that the pattern shape quality tends to be better below 1.1 GHz for the HTS spiral as compared to the gold spiral.

TERMINATED SPIRAL RESULTS

The tests done on 23 December 1994 were performed in a manner to allow a complete characterization of the spiral's response. These data was obtained using a vector network analyzer as the receiver. The transmit antenna was a linear polarized horn, which was placed in vertical polarization, and then horizontal polarization. By obtaining the relative amplitude and phase response to two orthogonal linear polarizations, any sense of polarization response can be determined for the receive antenna. This type test will allow any type of linear or elliptical polarization response for the spirals to be determined from the test data.

In addition, the spirals were also tested at two physical positions, which were 180 degrees in rotation different. The hope was that any errors induced by the test chamber could be averaged out of the tests.

The test data was analyzed by importing these data into a spreadsheet which was set up to determine the axial ratio, the left and right circular polarization responses, and the tilt angle of the spiral's ellipse response. From this data, the pattern axial ratio maximums and minimums were plotted and compared between the HTS and gold spirals, along with the right to left circular polarization ratio (antennas were built to be right hand circular), and the ellipse tilt angle.

The spiral pattern response for the maximum and minimum determined levels of the antenna's ellipse are compared in Figure 1, for the HTS and gold 3-inch spirals.

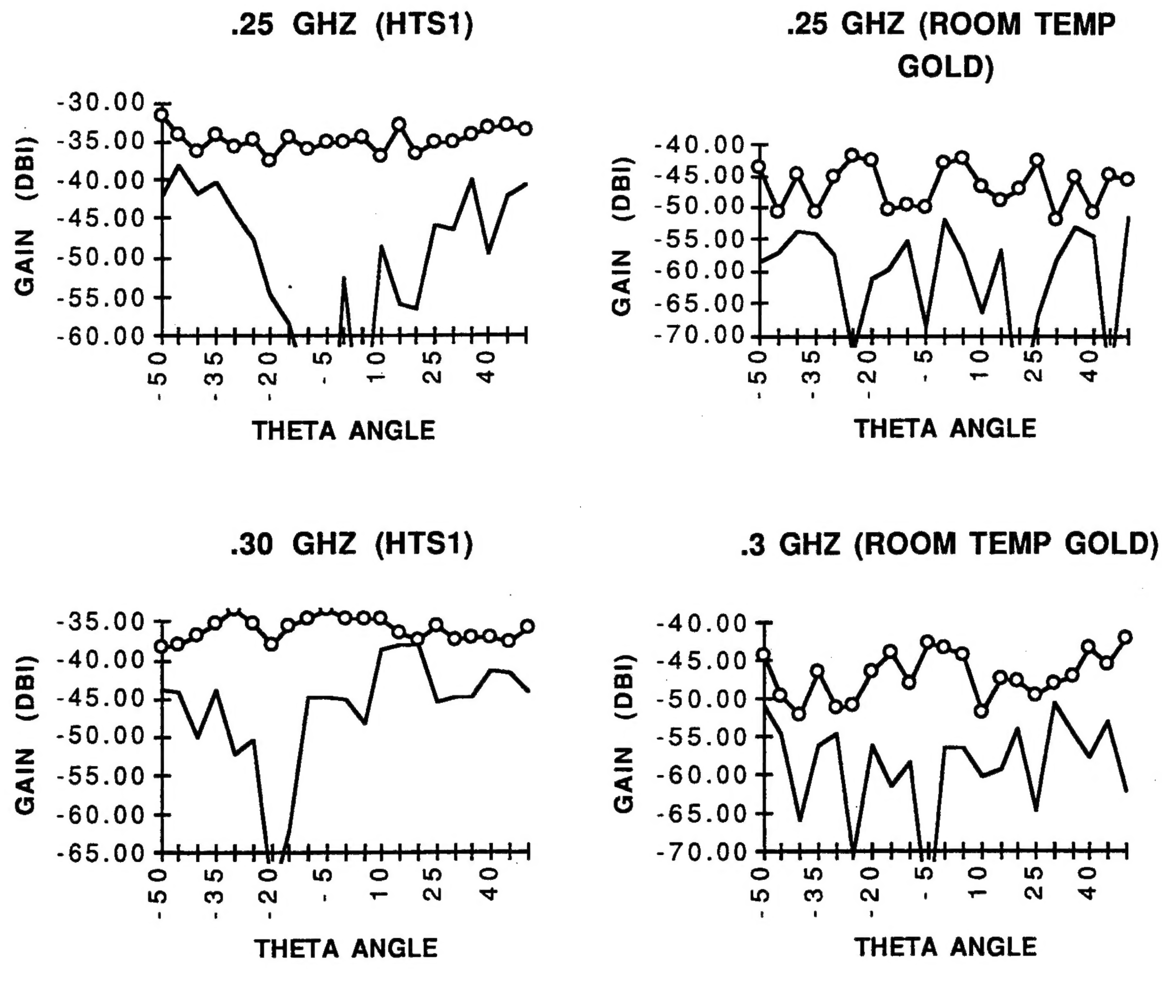
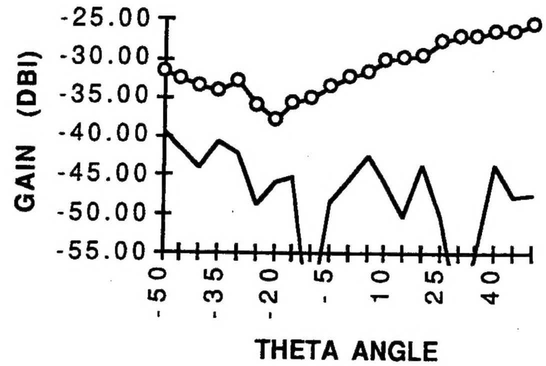
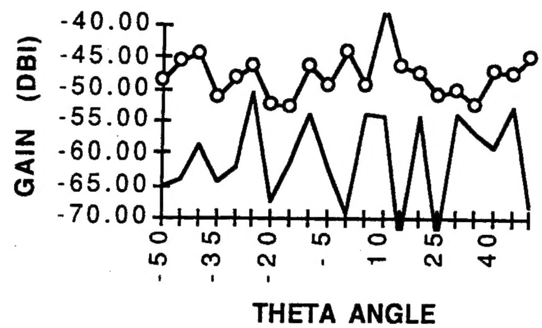


FIGURE 1. 3-Inch-Diameter Archimedean Spiral: HTSC to Normal Metal Comparison.

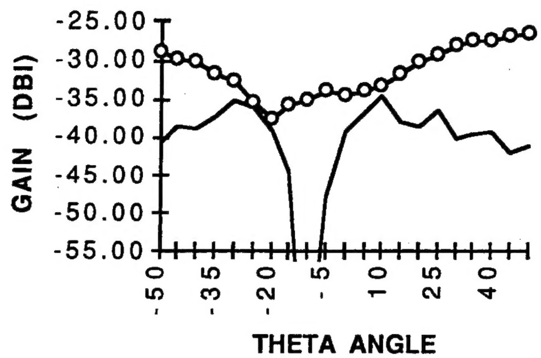
.35 GHZ (HTS1)



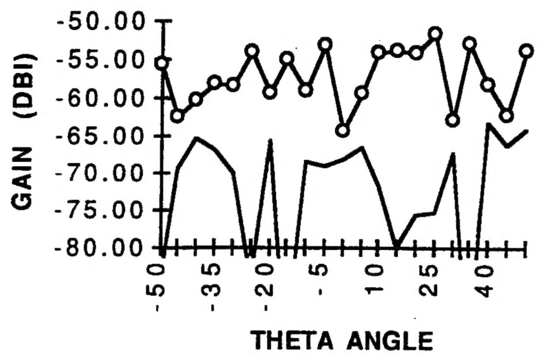
.35 GHZ (ROOM TEMP GOLD)



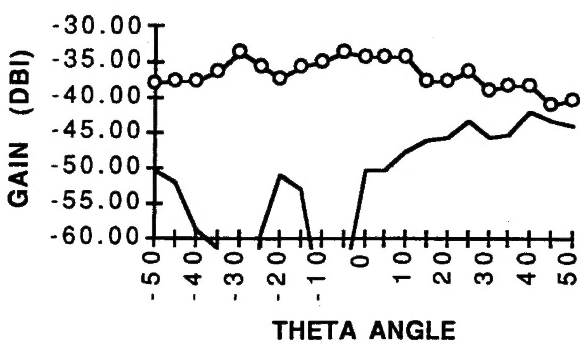
.4 GHZ (HTS1)



.4 GHZ (ROOM TEMP GOLD)



.45 GHZ (HTS1)



.45 GHZ (ROOM TEMP GOLD)

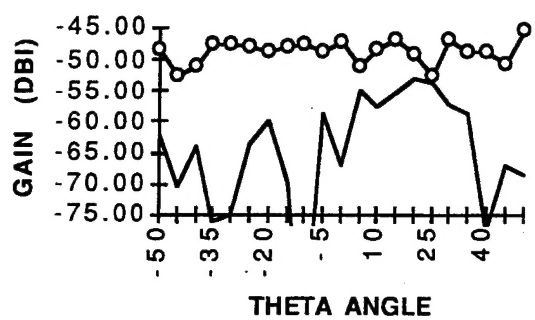


FIGURE 1. (Contd.)

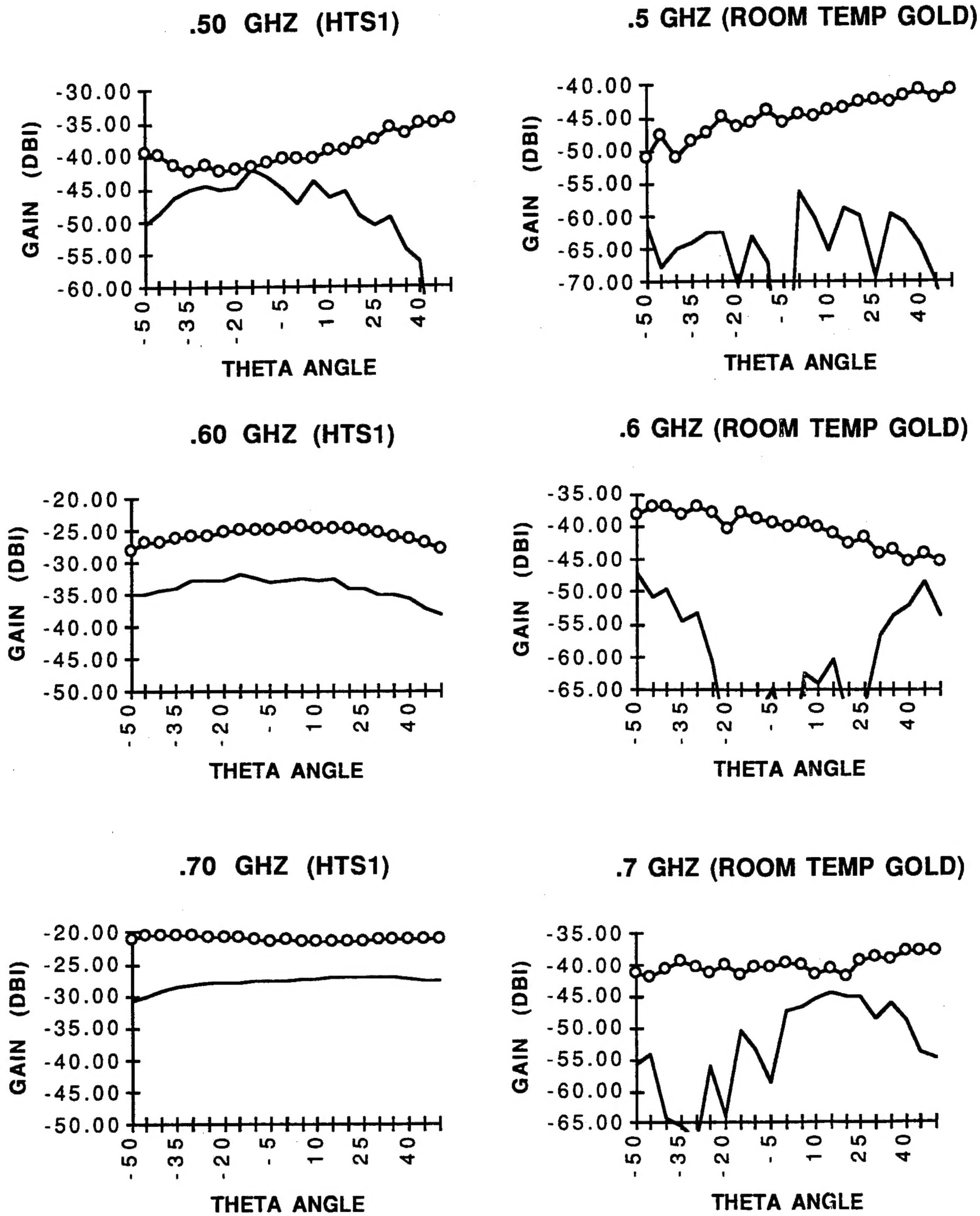


FIGURE 1. (Contd.)

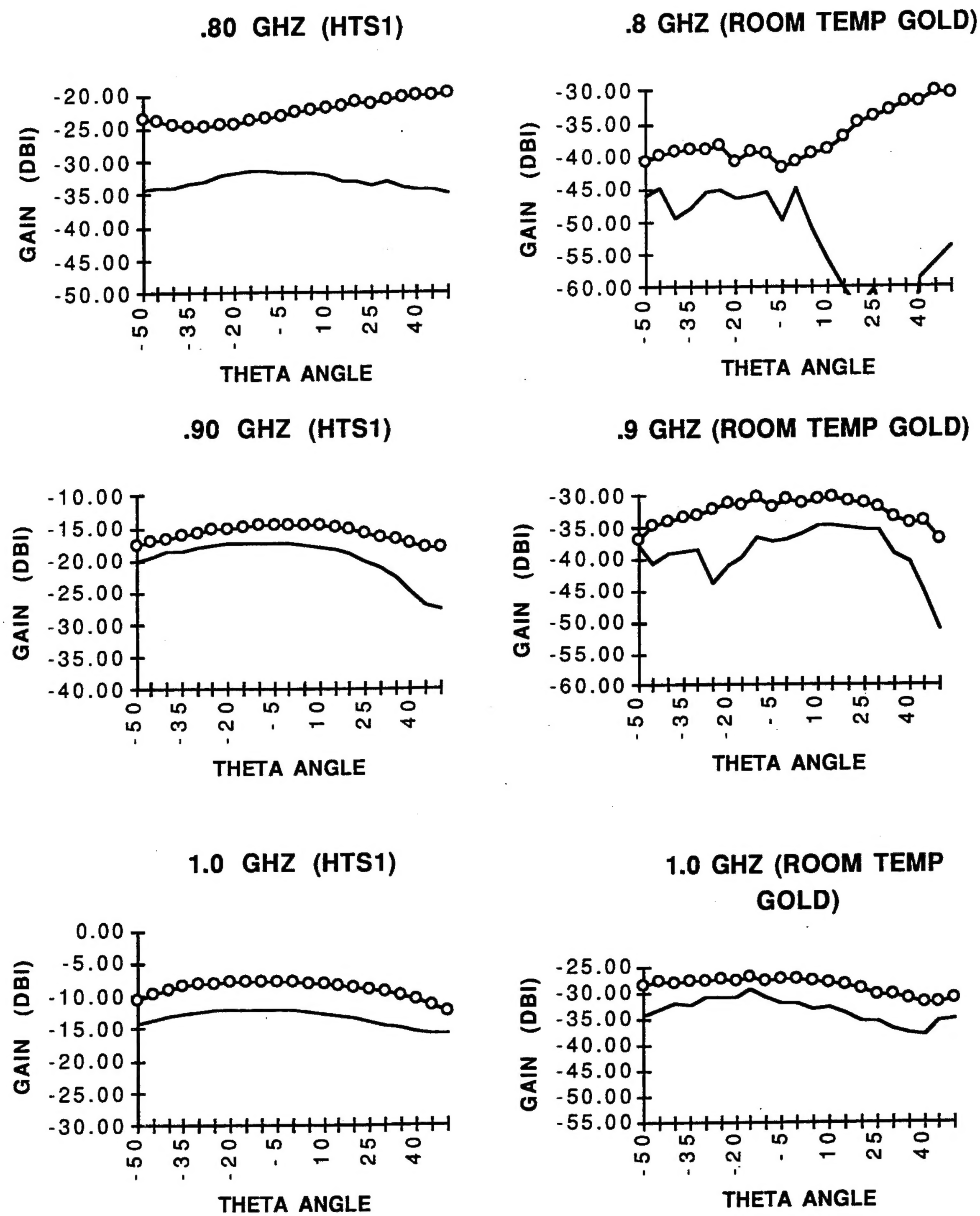


FIGURE 1. (Contd.)

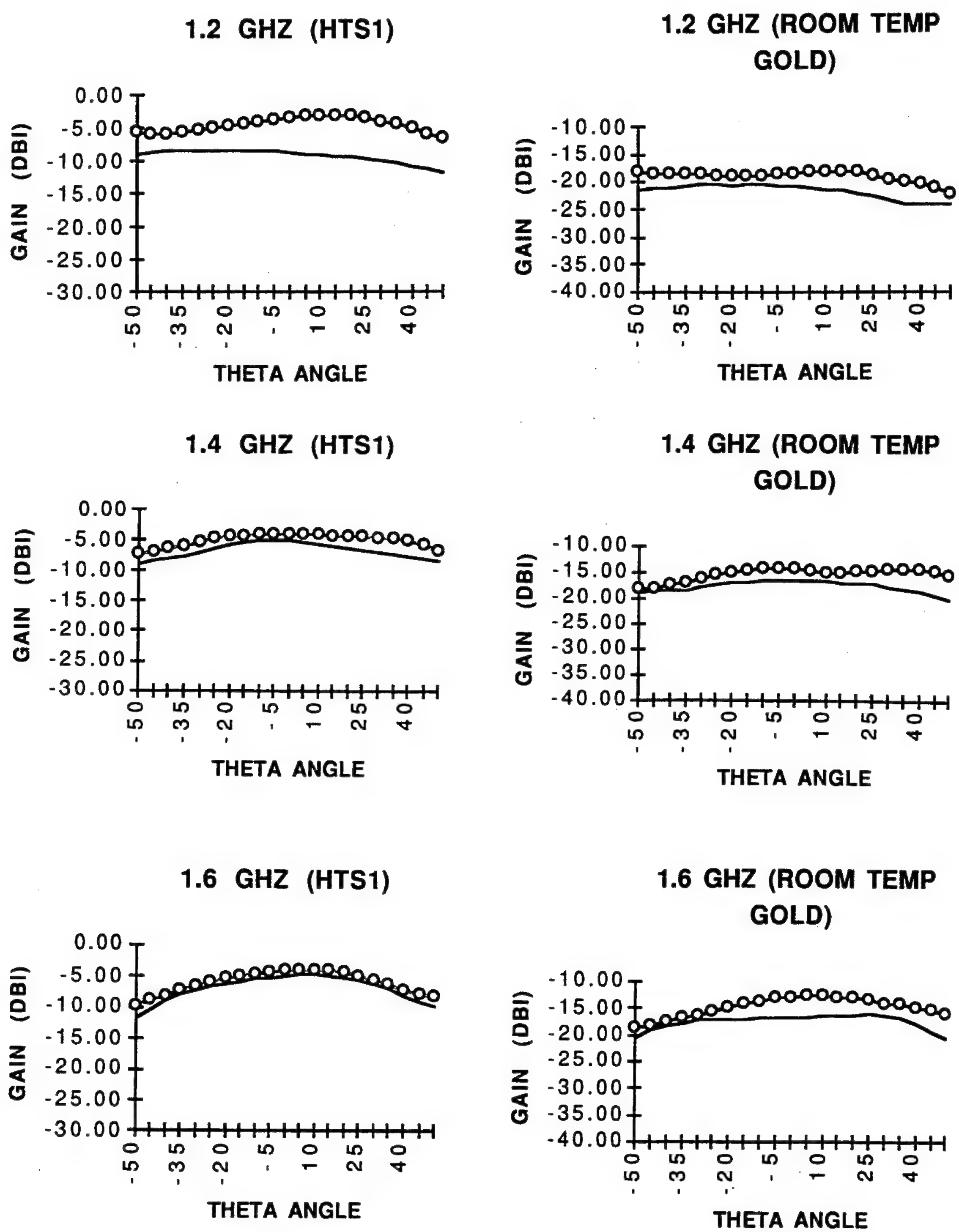
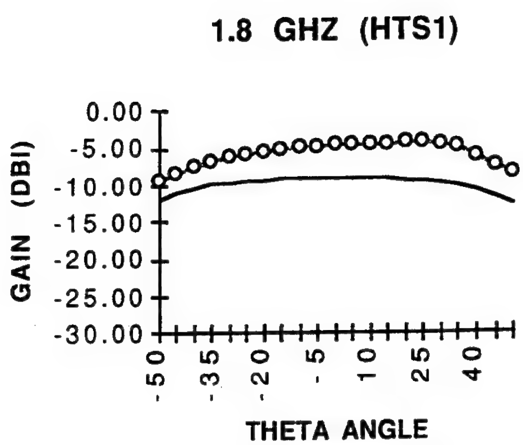


FIGURE 1. (Contd.)



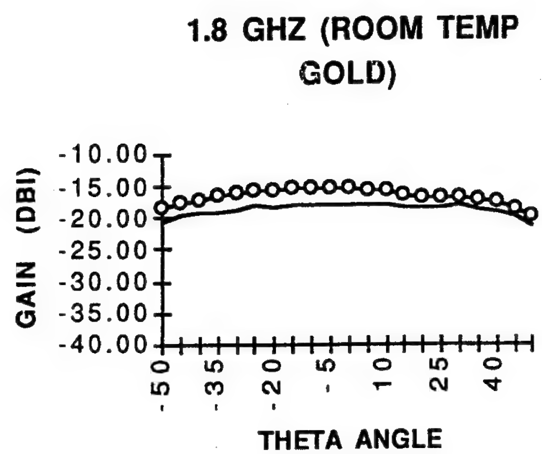


FIGURE 1. (Contd.)

These data from these tests indicates the frequency extension advantage of the HTS spiral. The lowest frequency for a 3-inch-diameter spiral is around 1.1 GHz. This can be seen in the gold spiral data. The patterns for the gold spiral are smooth, with a low axial ratio, down to 1 GHz. At 0.9 GHz the axial ratio begins to increase and the pattern shape starts to degrade. From 0.8 down to 0.5 GHz the pattern shape degrades drastically.

For the HTS spiral, the axial ratio increases some below 0.9 GHz, but the pattern shape doesn't start to degrade until 0.5 GHz. This illustrates low frequency extension of good quality patterns by a factor of 2. The patterns below 0.5 GHz begin to have high axial ratios and the minimums have a poor pattern shape. For some applications, there may still be some use, due to the increased gain.

The gain increase of the HTS spiral over the gold spiral is one of the most notable qualities. A graph of the HTS and gold spiral gains is illustrated in Figure 2.

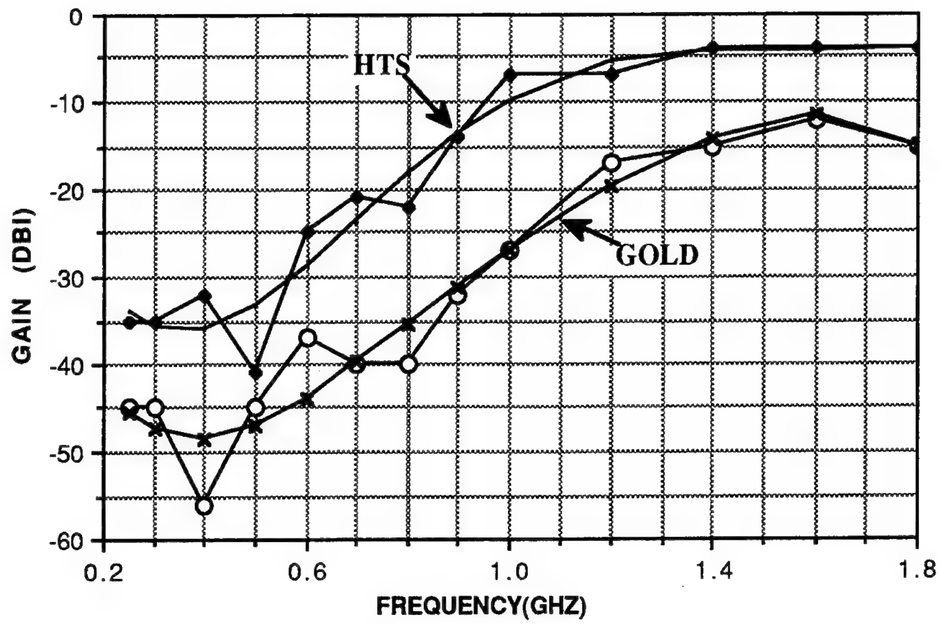


FIGURE 2. Gains of Terminated 3-Inch Spirals (HTS and Gold): Best Polarization Response.

At the upper frequencies where the gain becomes constant, there is a 10 dB improvement in the HTS spiral gain compared to the gold spiral. At 0.5 GHz, where the pattern quality is still good, the HTS spiral has a 15 dB gain improvement. The gain improvement over frequency for the smoothed data is illustrated in Figure 3.

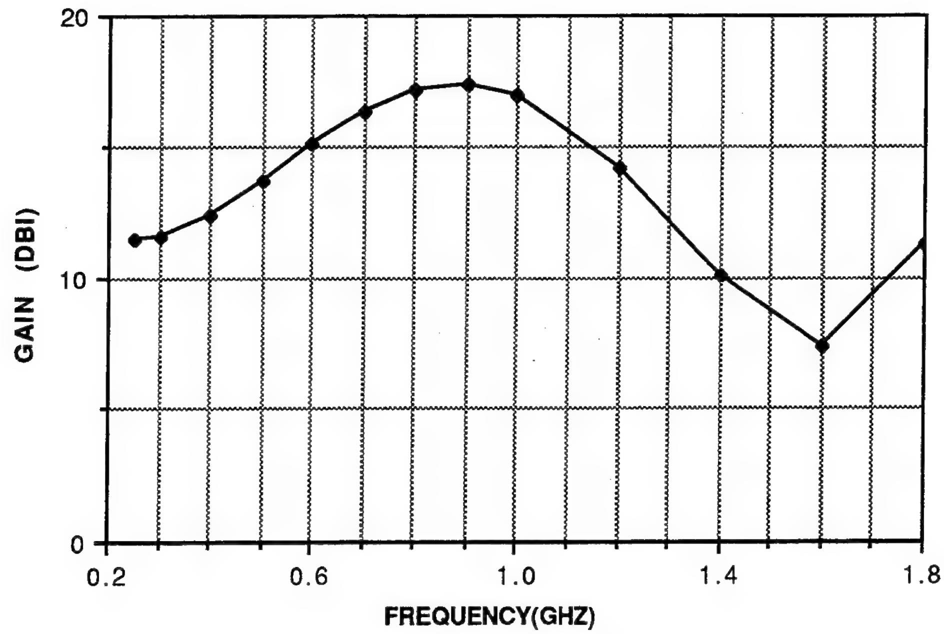


FIGURE 3. Smoothed Delta Gain Between Terminated 3-Inch Spirals (HTS and Gold): Best Polarization Response.

This data indicates the increasing gain as the frequency drops, which levels out at 17 dB at 0.85 GHz and decreases somewhat below that.

It should be noted that a comparison of the patterns shown above to the patterns shown in the final report by AEL Industries will show different gains and pattern shapes. This is due to most of the patterns shown in the AEL Industries report being the vertical polarization patterns. For a number of cases, this data tended to exaggerate the difference between the HTS and gold spirals. The total elliptical response gives the most complete indication of the spiral's performance.

The other difference between the data shown above and AEL Industries data was caused by the loss of the cables and baluns used during the tests. These data above is taken strictly from the tested spiral's power levels, which would include the loss of the spiral's balun. The cable and balun losses were not documented in AEL Industries final report. The subtraction of this loss would give the spiral's actual absolute gain, and thus, the difference between the peak gains shown above (-5 dBi) and the 2 dBi peak gain indicated in AEL Industries final report. This will not affect the measurement of the difference between the HTS and gold spirals, however. Each set of tests had the same cables and balun in the hardware used.

(Note: On 12 July 1995 I received data on the cable and balun loss from AEL Industries. This loss was taken out of the measured pattern data and is plotted versus AEL Industries gain curve data in Figure 4. These data supplied by AEL Industries and a loss-versus-frequency curve is in Appendix C.)

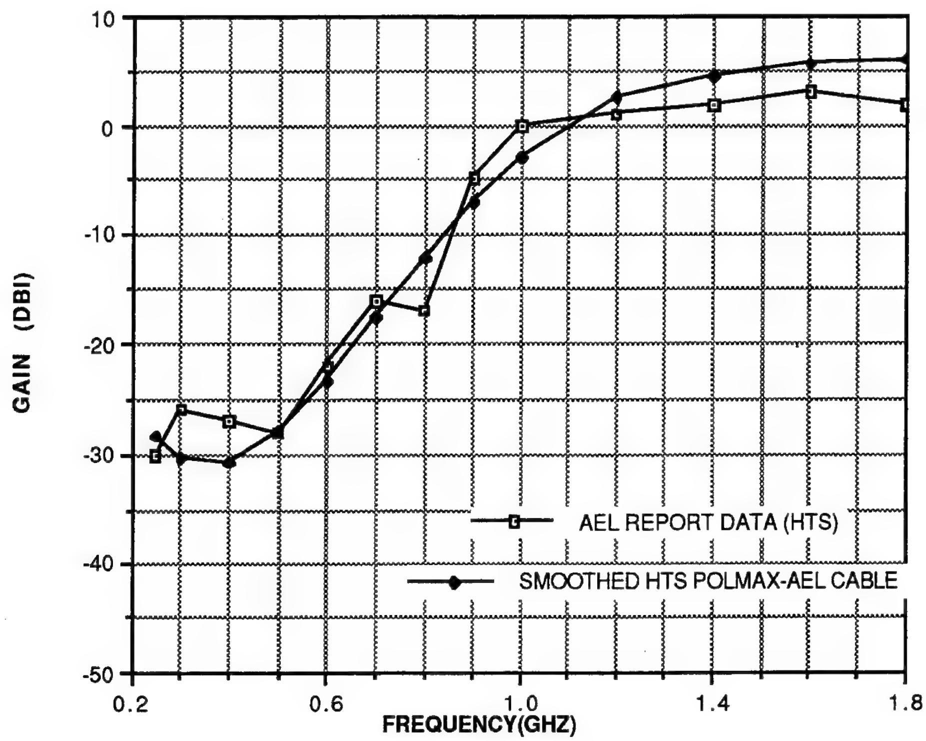


FIGURE 4. Measured Gain of 3-Inch Spiral (Minus Cable Loss) Versus AEL Industries Reported Gain.

The two sets of data show very good agreement, with the loss-corrected gain calculated at NAWC being even higher than expected.

The balun loss seems to be quite high for these frequencies, however. Typical balun losses for an off-the-shelf balun at 0.5 GHz are about 0.2 dB. Any future designs should have the balun perfomance looked at closely.

Two other factors evaluated from these tests were the circular polarization purity and the polarization ellipse tilt angle. This ratio indicates another quality of the antenna that needs to be evaluated as the frequency performance is pushed lower. Spiral antennas are generally used because of their broad bandwidth and circular polarization. If the circular polarization degrades, the advantage of using a spiral is lost. The ratio of right- to left-hand circular polarization indicates how much this quality degrades. For the case of the spirals tested, the arm windings were made in a right-hand sense. If the spirals have good quality circular polarization, the right- to left-hand ratio will be high. A ratio of 0 dB indicates equal power response to either sense, which actually results in a linear polarization. A negative ratio indicates the polarization is becoming opposite to what was intended.

The comparative plots of the right- to left-hand circular polarization ratio for the HTS and gold antennas are illustrated in Figures 5.

HTS | GOLD

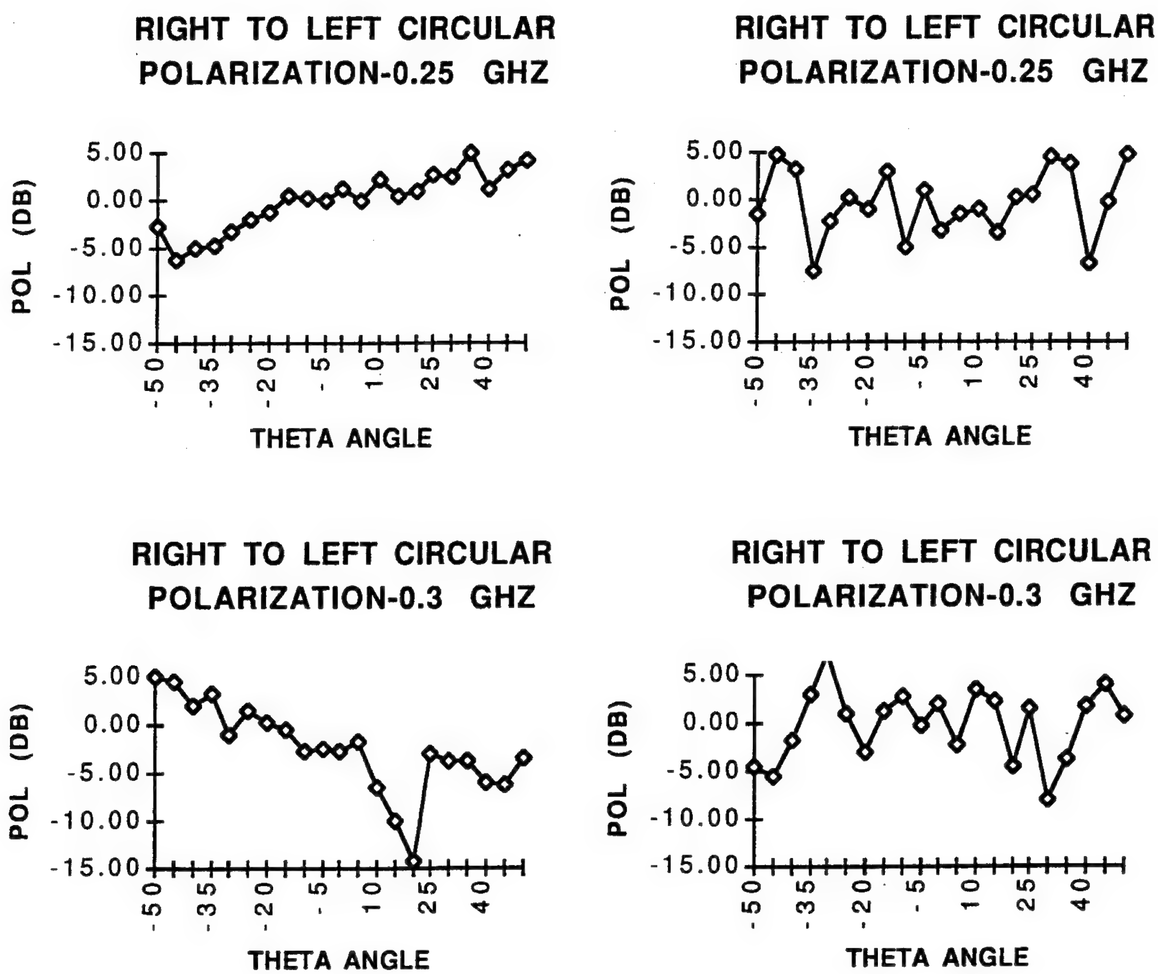
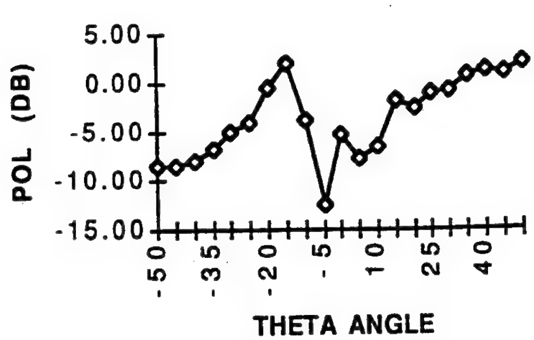


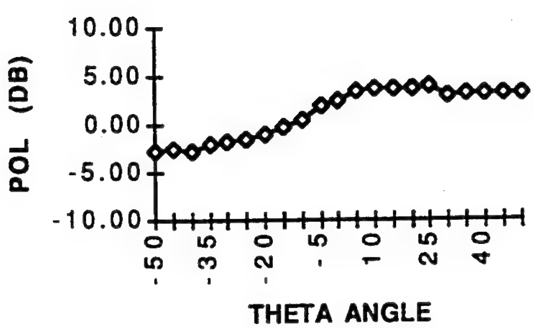
FIGURE 5. Comparative Plots of the Right- to Left-Hand Circular Polarization Ratio.

HTS

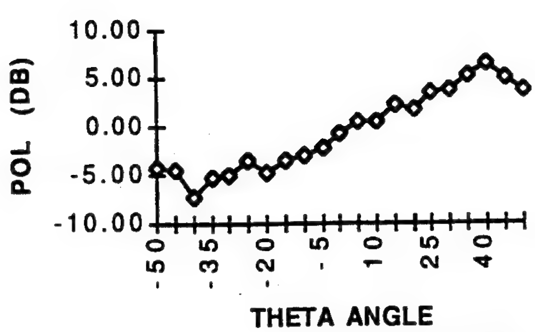
RIGHT TO LEFT CIRCULAR POLARIZATION-0.35 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.4 GHZ

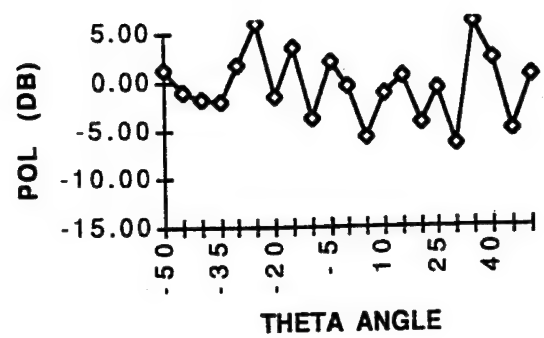


RIGHT TO LEFT CIRCULAR POLARIZATION- .45 GHZ

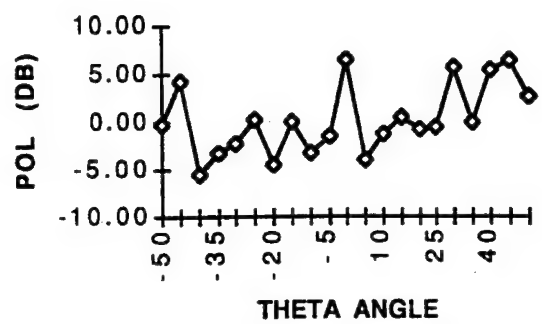


GOLD

RIGHT TO LEFT CIRCULAR POLARIZATION-0.35 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.4 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.45 GHZ

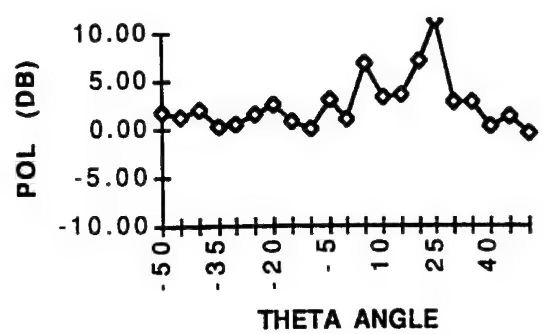


FIGURE 5. (Contd.)

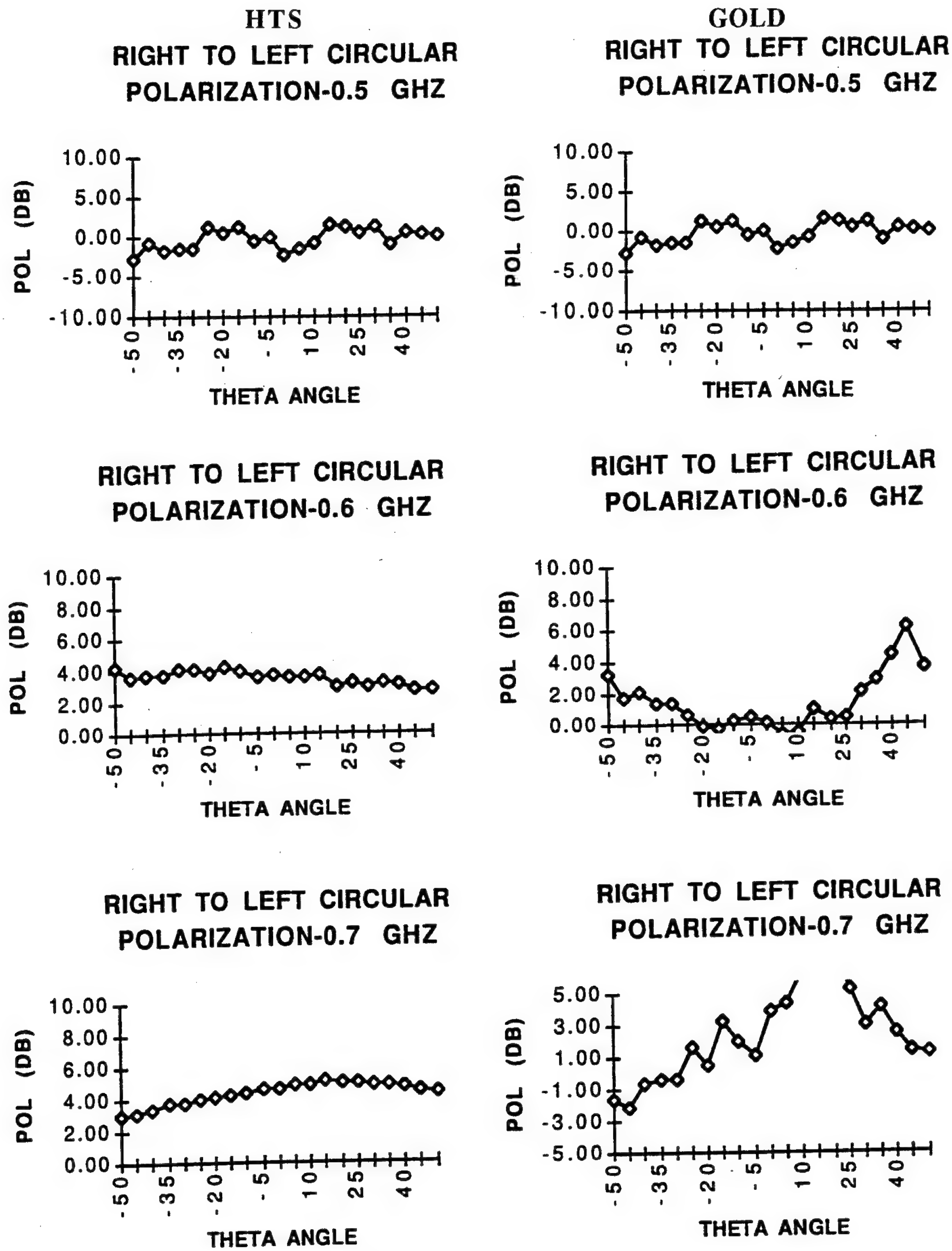
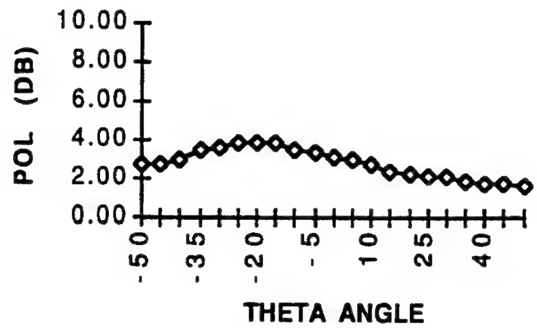


FIGURE 5. (Contd.)

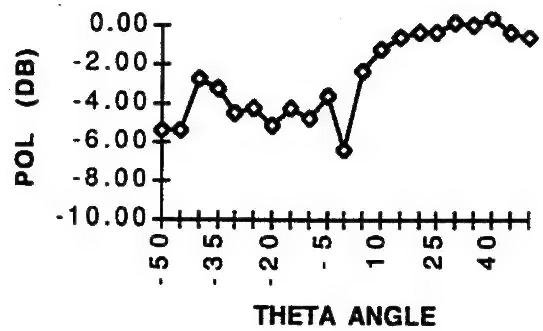
HTS

GOLD

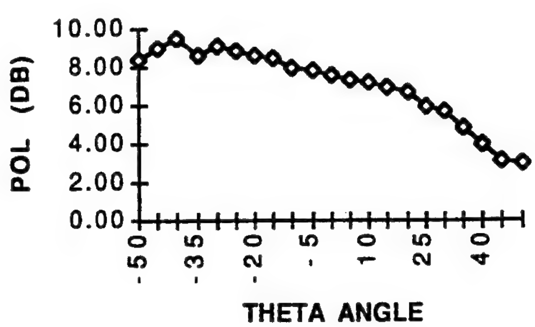
RIGHT TO LEFT CIRCULAR POLARIZATION-0.8 GHZ



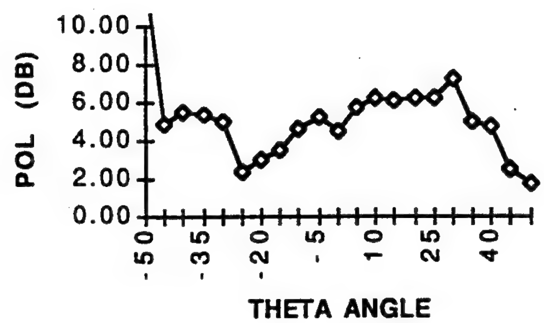
RIGHT TO LEFT CIRCULAR POLARIZATION-0.8 GHZ



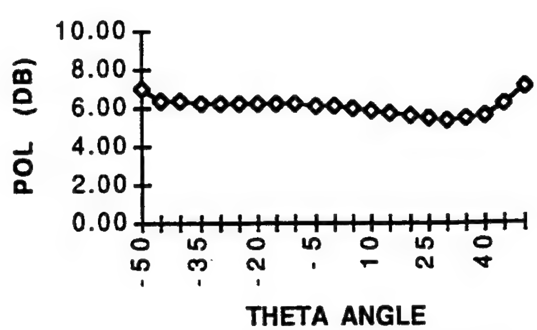
RIGHT TO LEFT CIRCULAR POLARIZATION-0.9 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.9 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1 GHZ

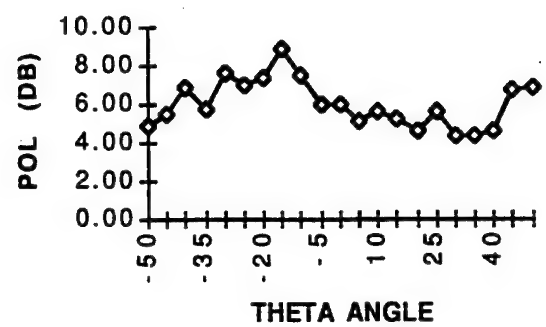
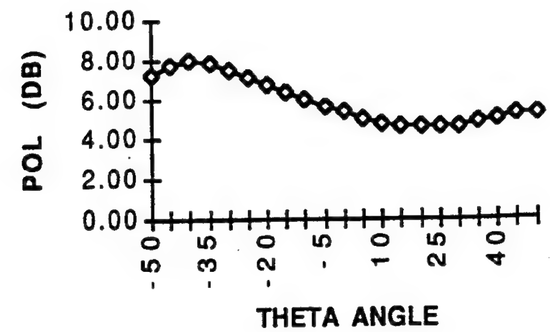


FIGURE 5. (Contd.)

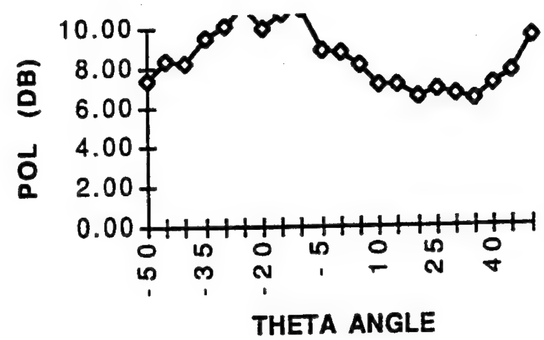
HTS

RIGHT TO LEFT CIRCULAR POLARIZATION-1.2 GHZ

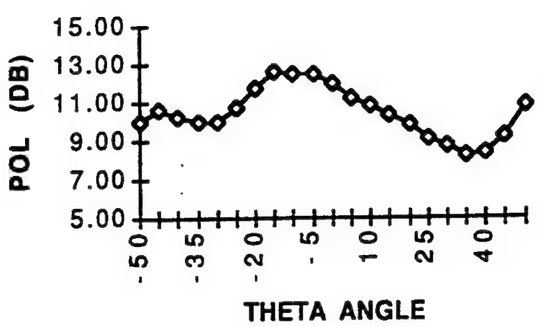


GOLD

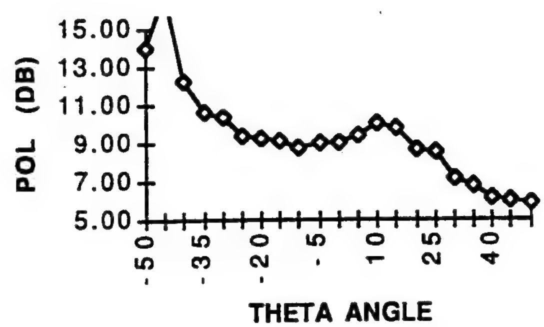
RIGHT TO LEFT CIRCULAR POLARIZATION-1.2 GHZ



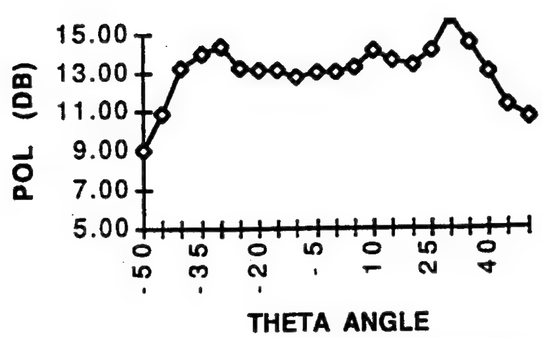
RIGHT TO LEFT CIRCULAR POLARIZATION-1.4 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.4 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.6 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.6 GHZ

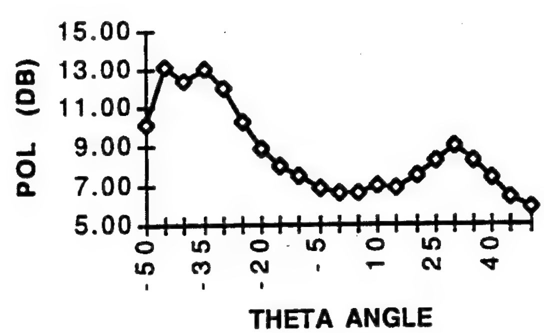
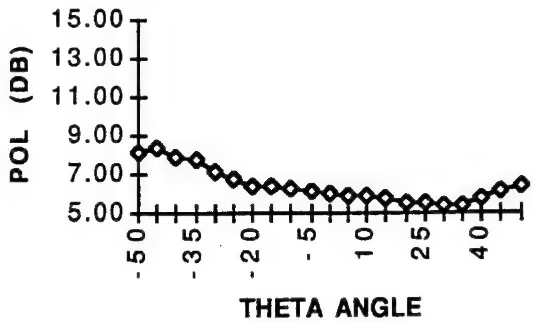


FIGURE 5. (Contd.)

HTS

RIGHT TO LEFT CIRCULAR POLARIZATION-1.8 GHZ



GOLD

RIGHT TO LEFT CIRCULAR POLARIZATION-1.8 GHZ

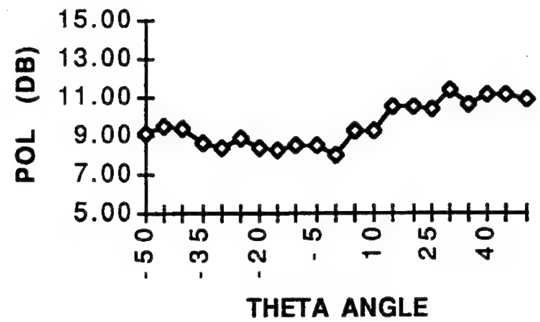


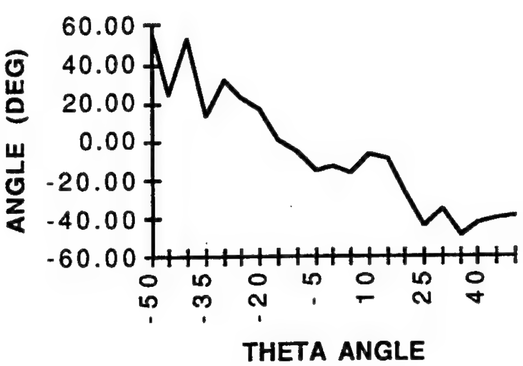
FIGURE 5. (Contd.)

The circular polarization ratio improvement is similar to the gain. The HTS spiral has a better ratio than the gold from about 1.0 to 0.5 GHz, which corresponds to the frequency range where the patterns are better. Below 0.5 GHz and above 1.0 GHz, this factor is about the same for either spiral.

The antenna's polarization ellipse angle was also evaluated for the HTS and gold spirals. These data are illustrated in Figures 6.

HTS

ELLIPSE ANGLE-0.25 GHZ



GOLD

ELLIPSE ANGLE-0.25 GHZ

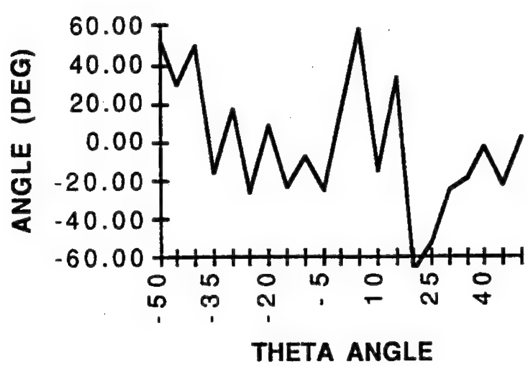


FIGURE 6. 3-Inch-Diameter Archimedean Spiral: HTSC to Normal Metal Comparison.

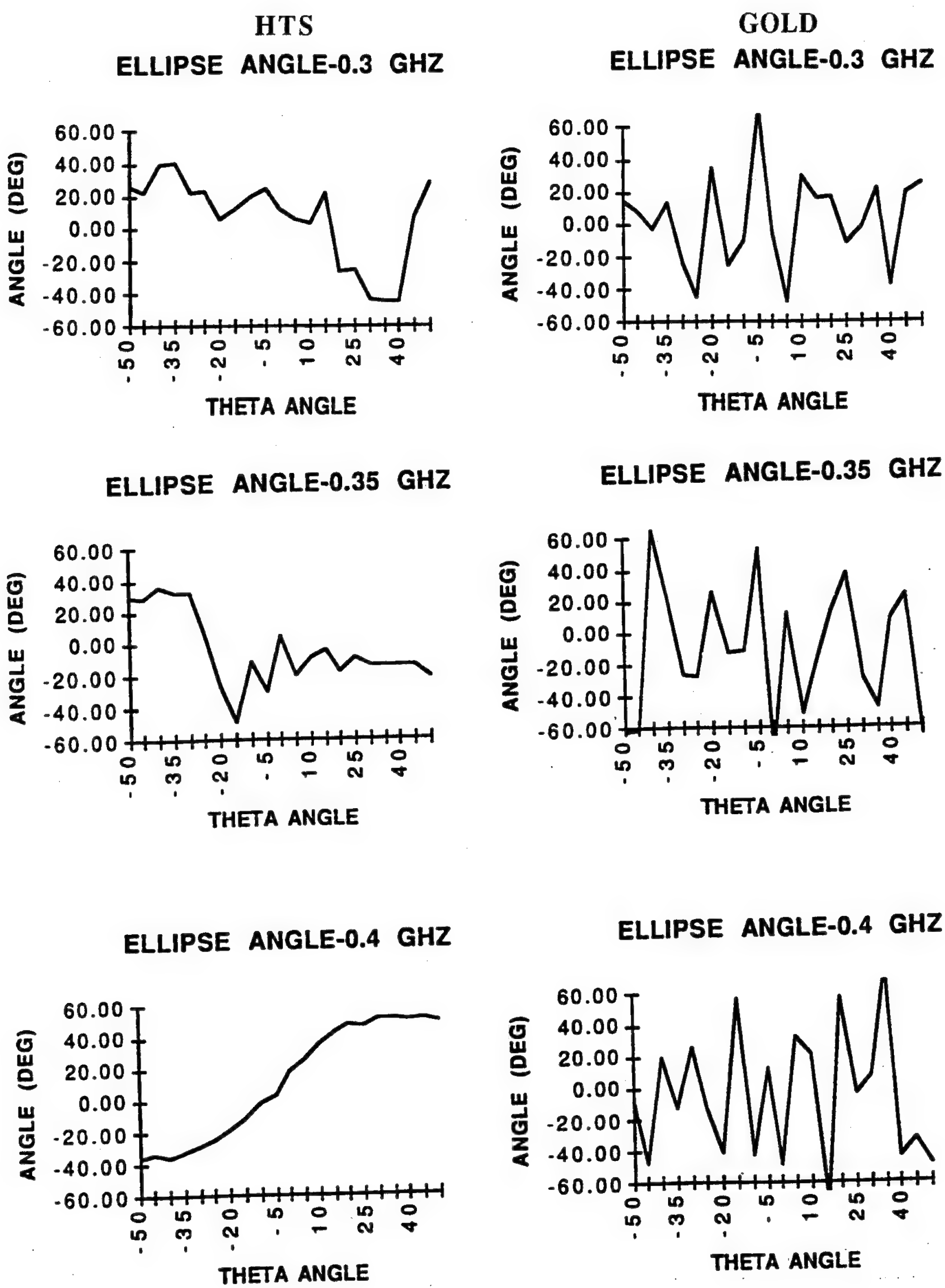


FIGURE 6. (Contd.)

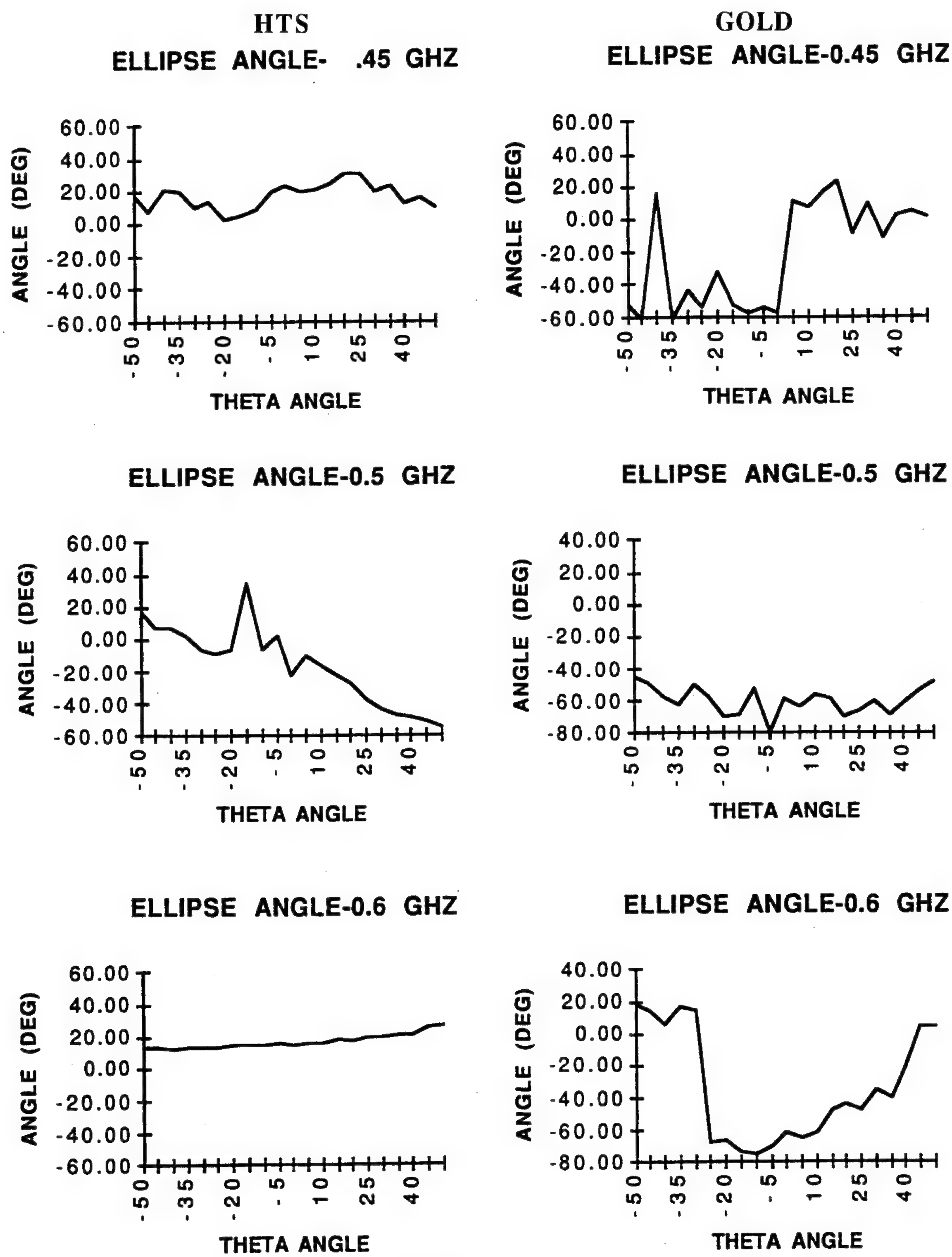


FIGURE 6. (Contd.)

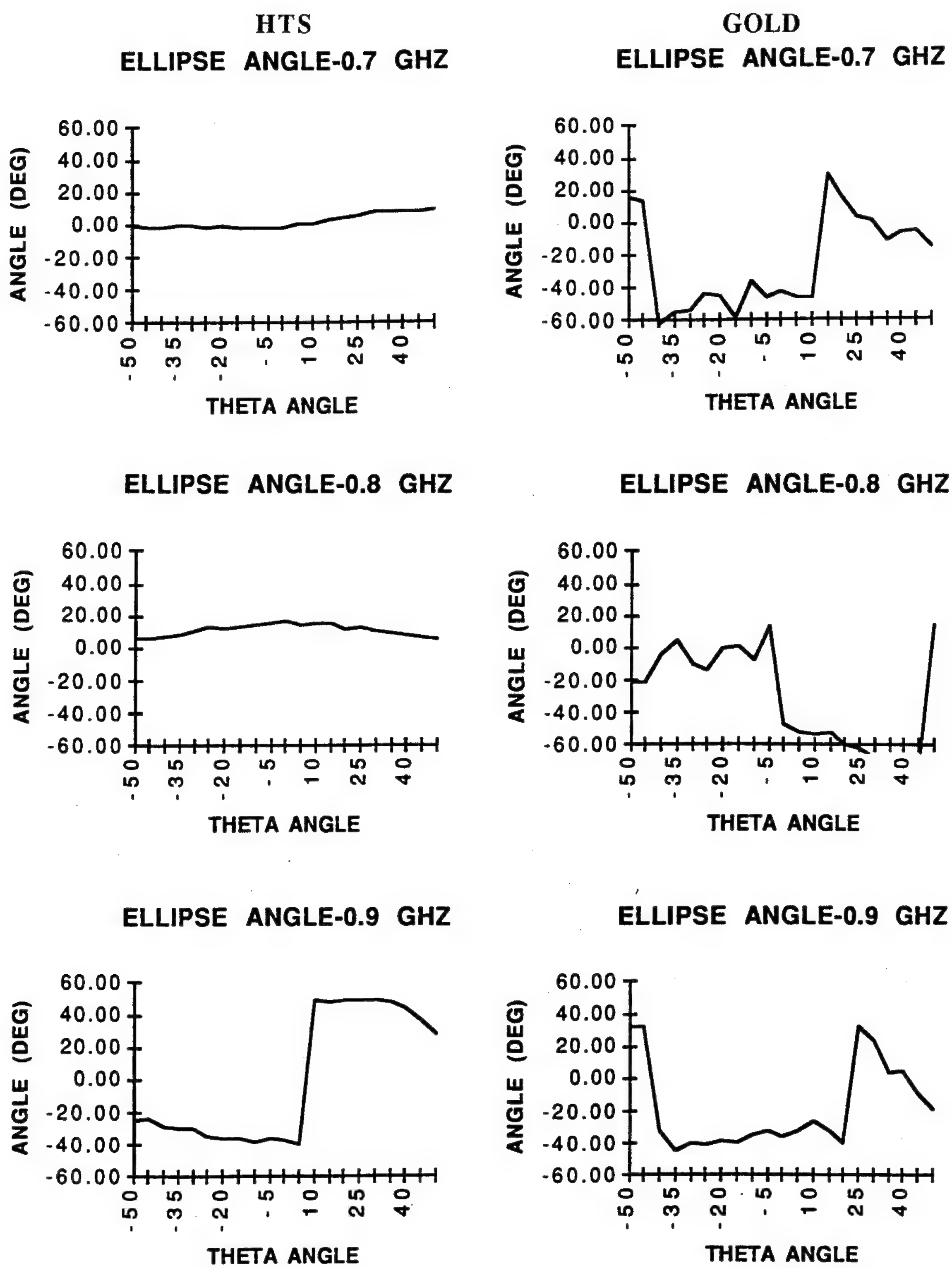


FIGURE 6. (Contd.)

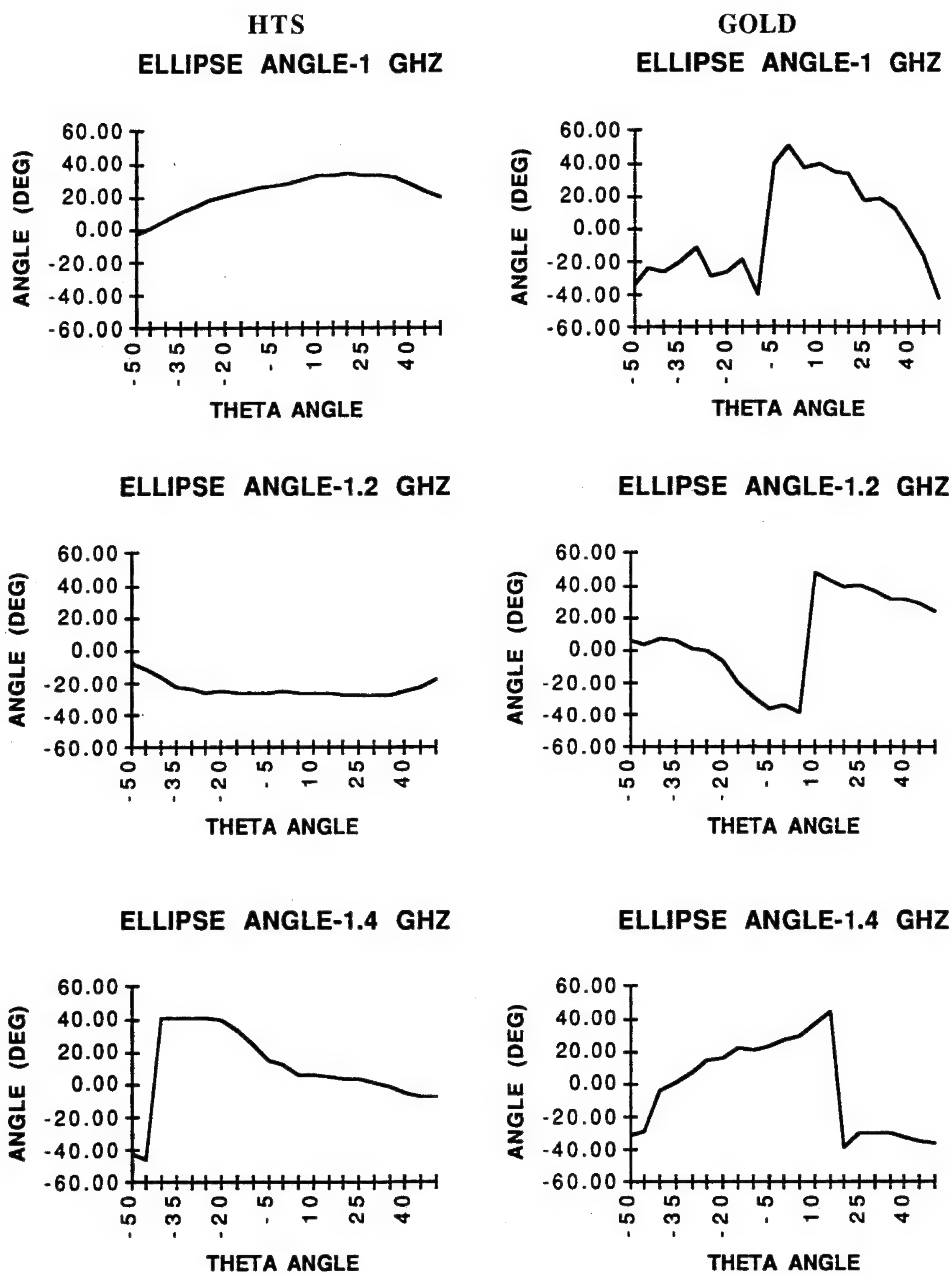


FIGURE 6. (Contd.)

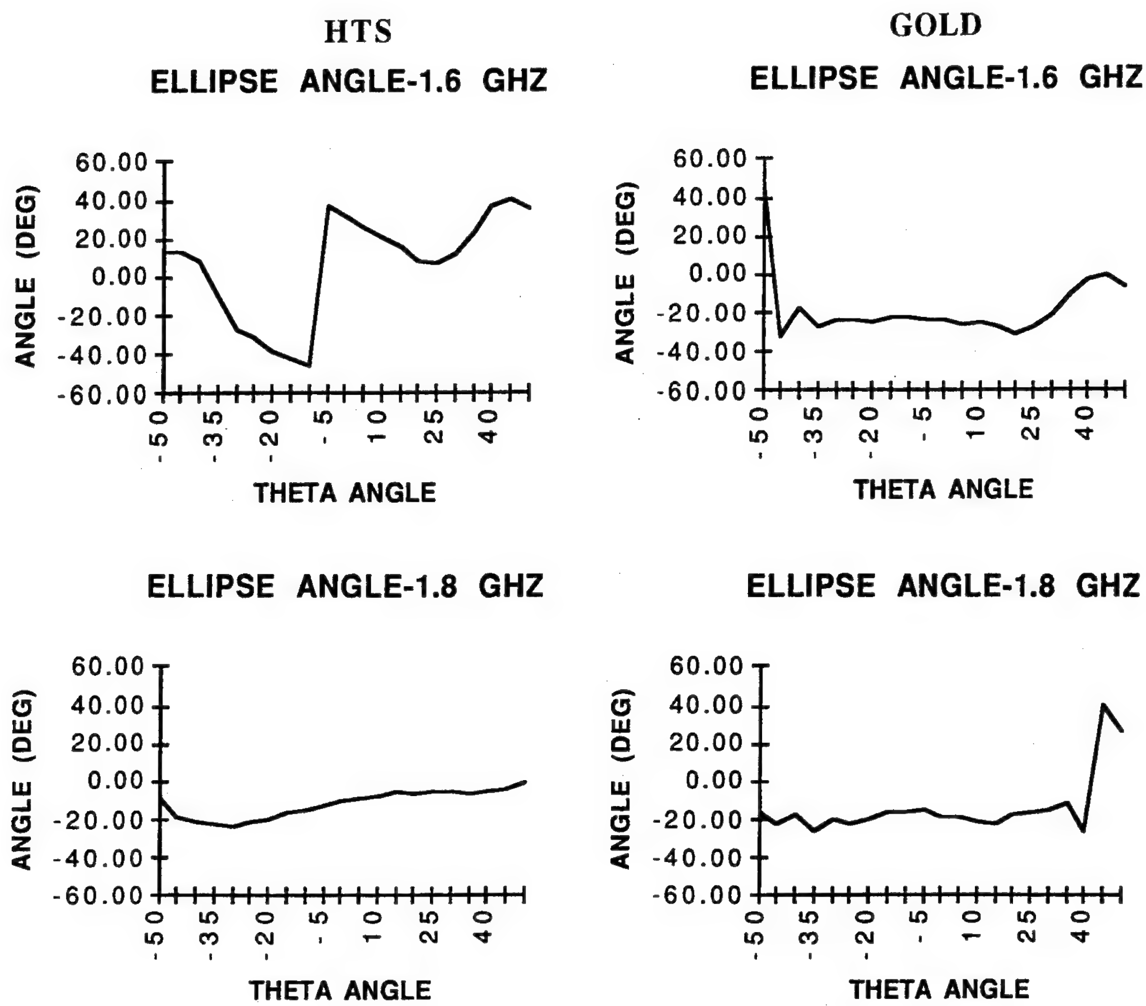


FIGURE 6. (Contd.)

The presentation of the ellipse angles is included for completeness. Its interpretation is something that is not clear at this time. However, it is noted that the gold spiral has more fluctuation of this parameter than the HTS.

The spirals were also tested at two different rotational positions. This type of additional testing can help to remove antenna chamber induced errors and azimuth angle pointing errors if the test antenna positioner is also rotated. These data are presented in Appendix D for the spiral patterns and polarization ratio. These data seem to indicate no noticeable changes with roll position. The manner in which the spirals were rotated for this test did not allow the error correction hoped for.

2-INCH SPIRAL TESTS

A set of 2-inch-diameter spirals were also built and tested on this project. The antenna arm geometry was modified to look at the possible further reduction in size for this type of design. The antenna arms were defined with a "modulated" arm geometry, which means that a gradually increasing amplitude sine wave is imposed on the standard Archimedean arms. This geometry will create additional length in the arms and theoretically will induce a "slow wave" to the energy propagation around the arms. The intended effect is to make the spiral current band occur at a smaller diameter, thus effectively making a spiral work lower in frequency. The patterns for the HTS and gold spirals are presented on Figures 7.

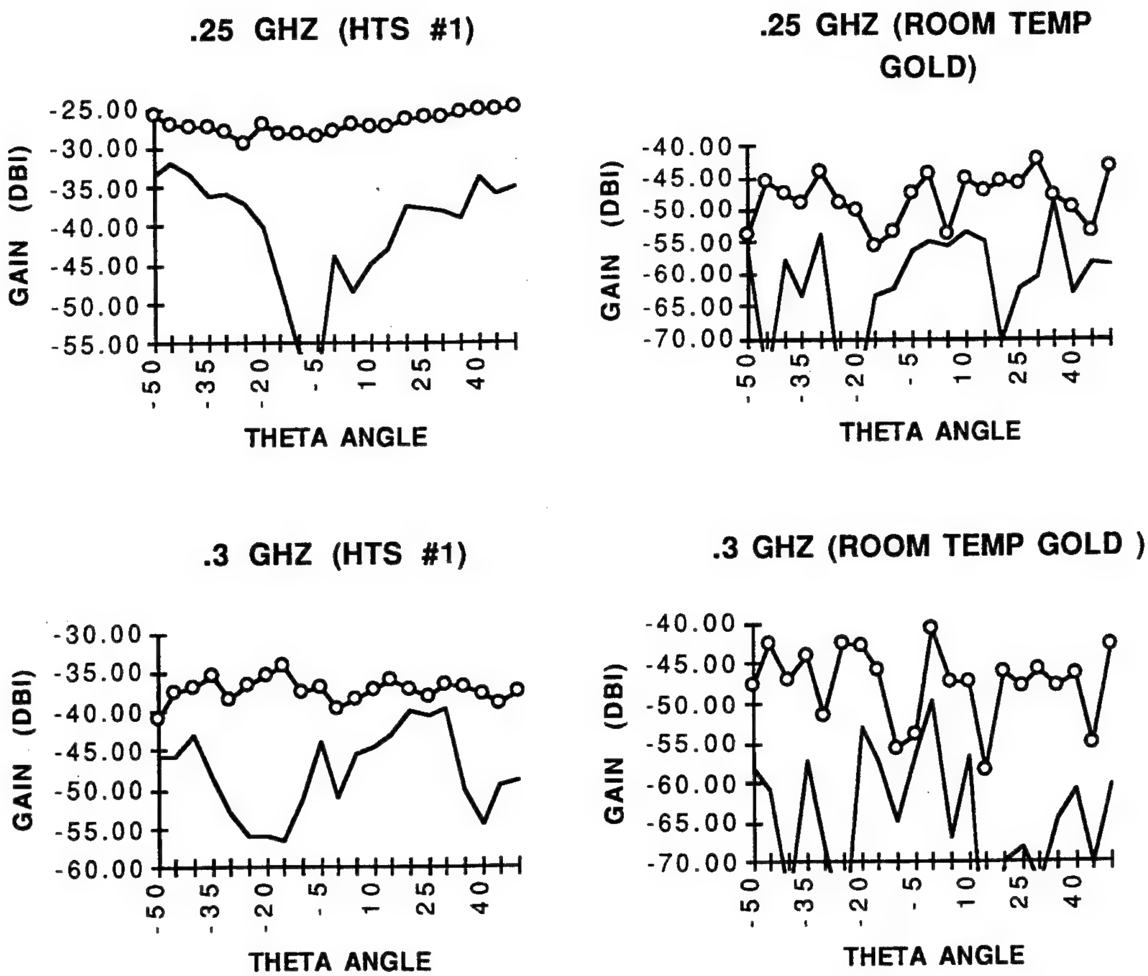


FIGURE 7. 2-Inch Diameter Archimedean Modulated Arm Sprial: HTSC to Normal Metal Comparison.

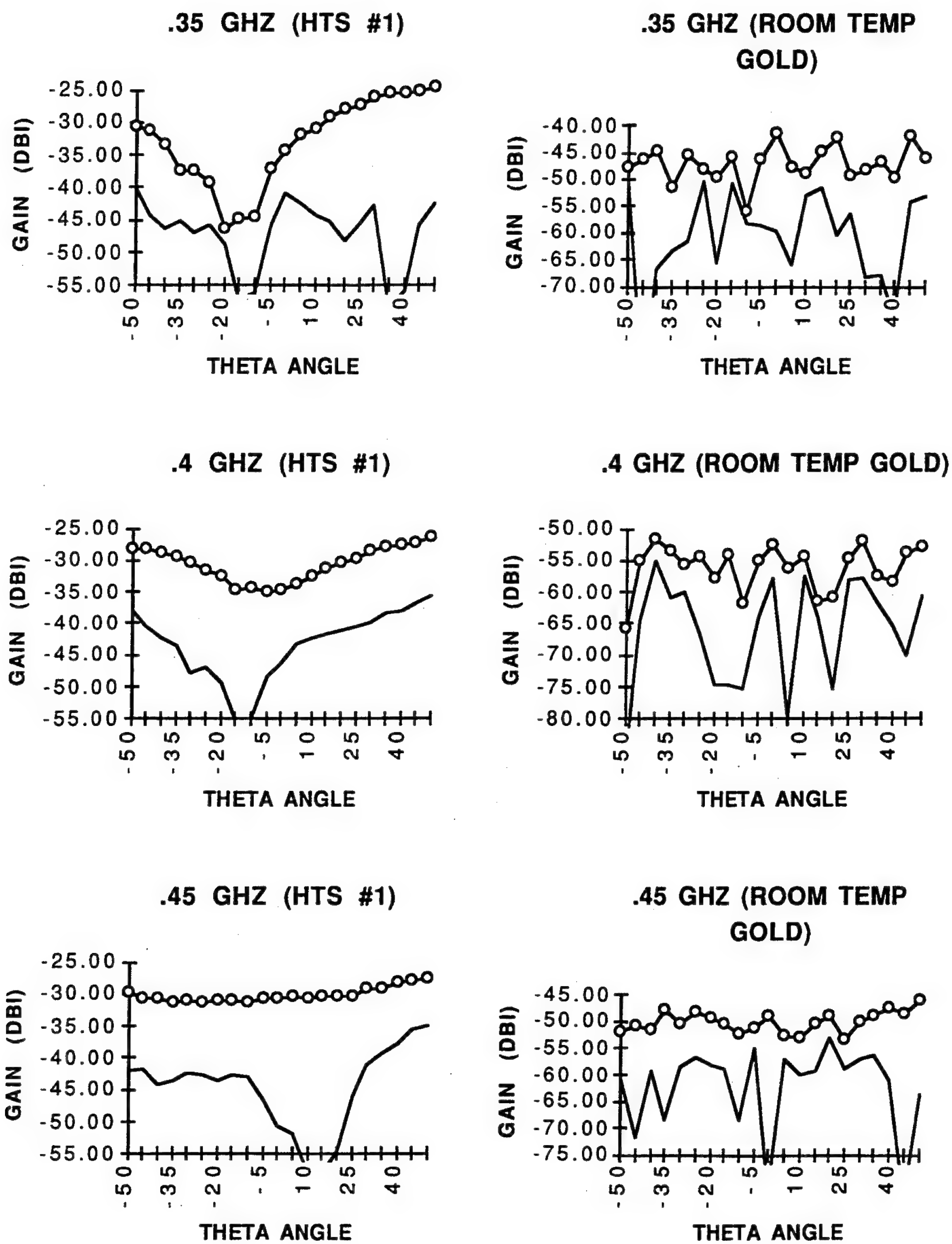


FIGURE 7. (Contd.)

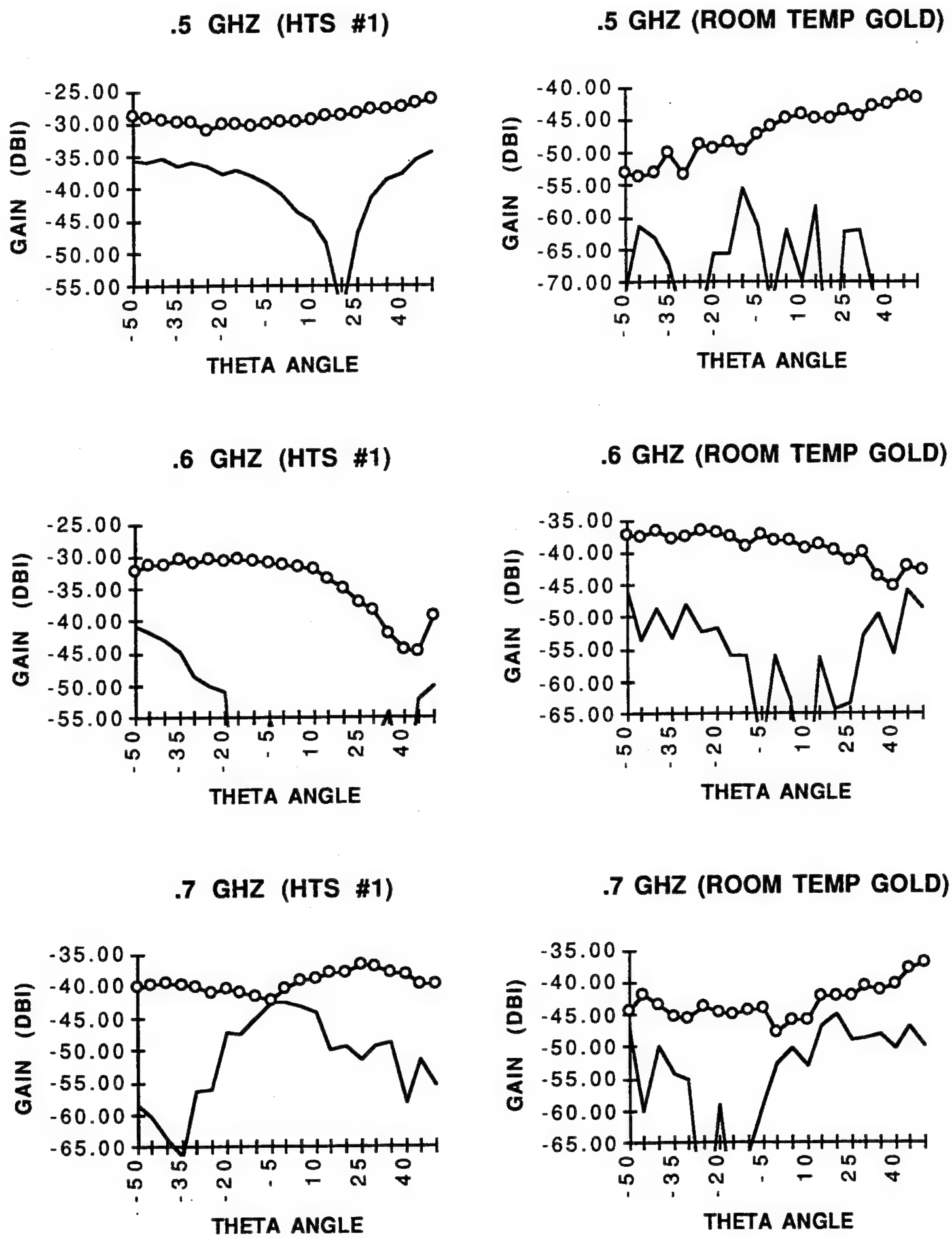
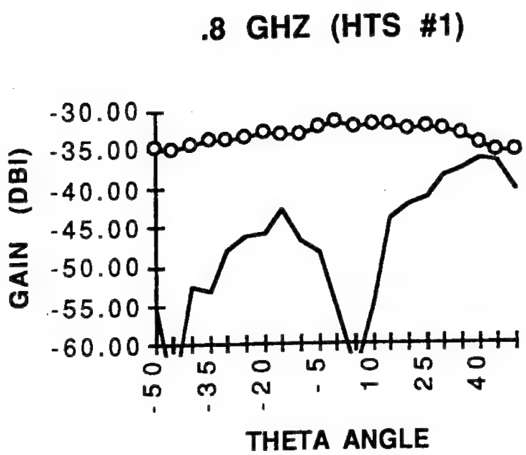
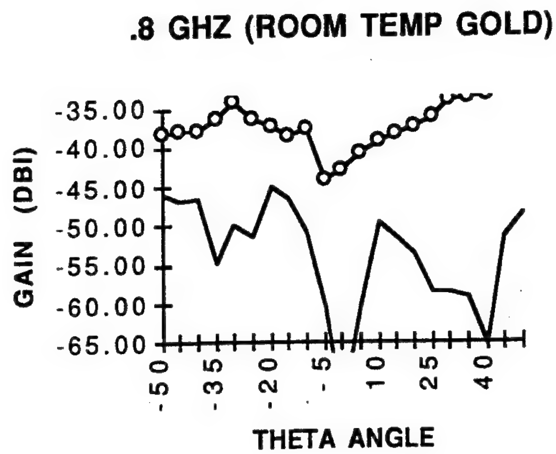
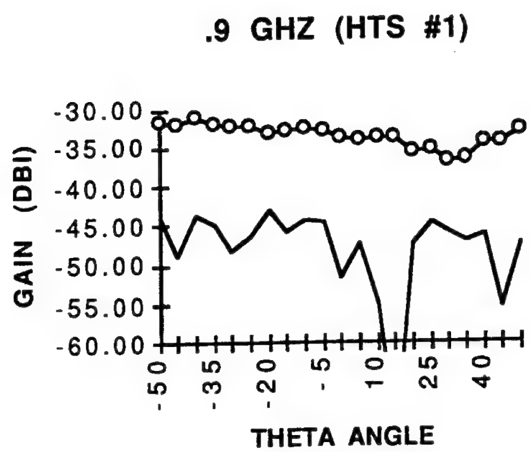
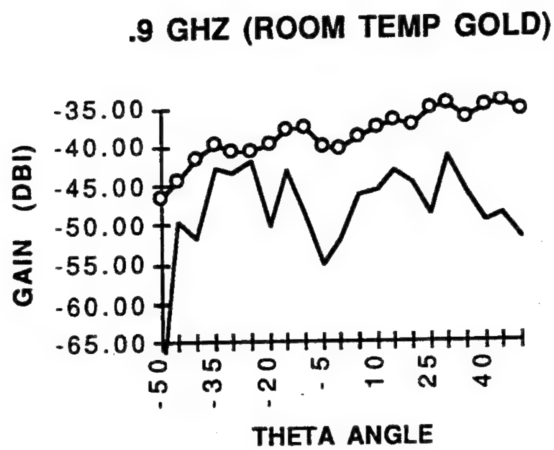


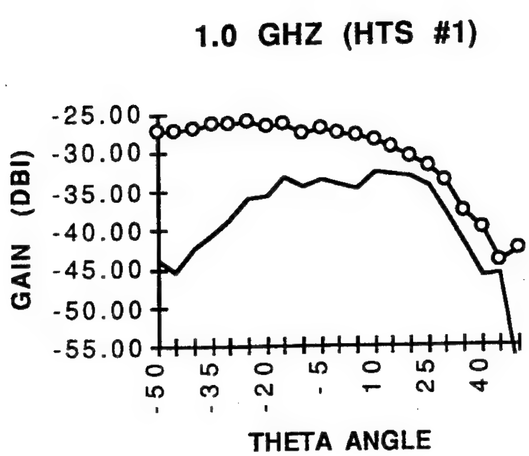
FIGURE 7. (Contd.)











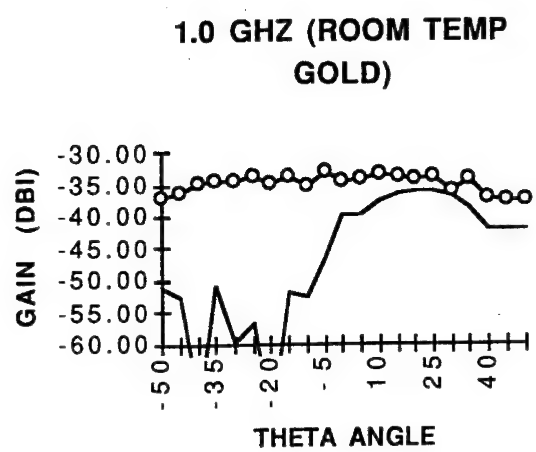


FIGURE 7. (Contd.)

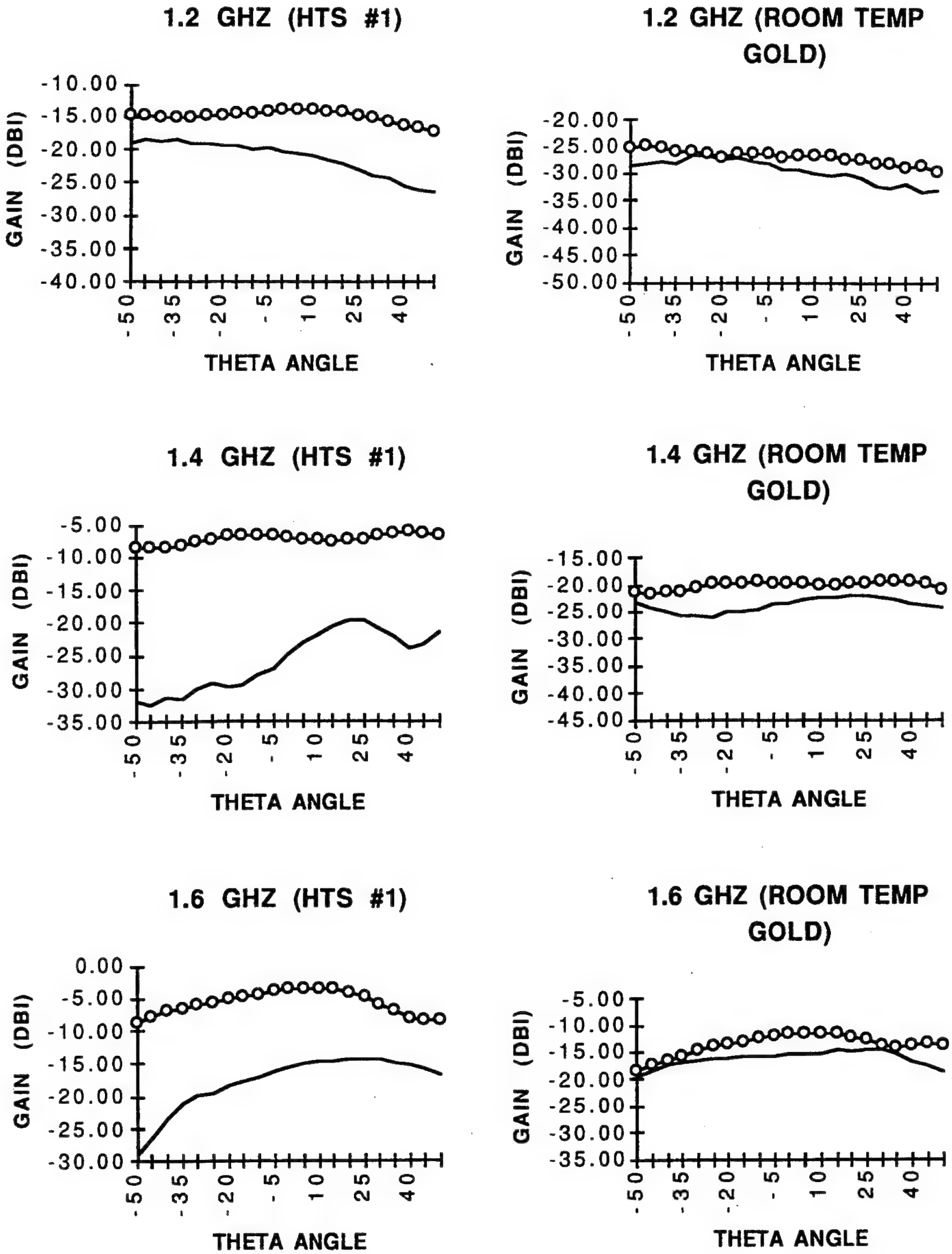


FIGURE 7. (Contd.)

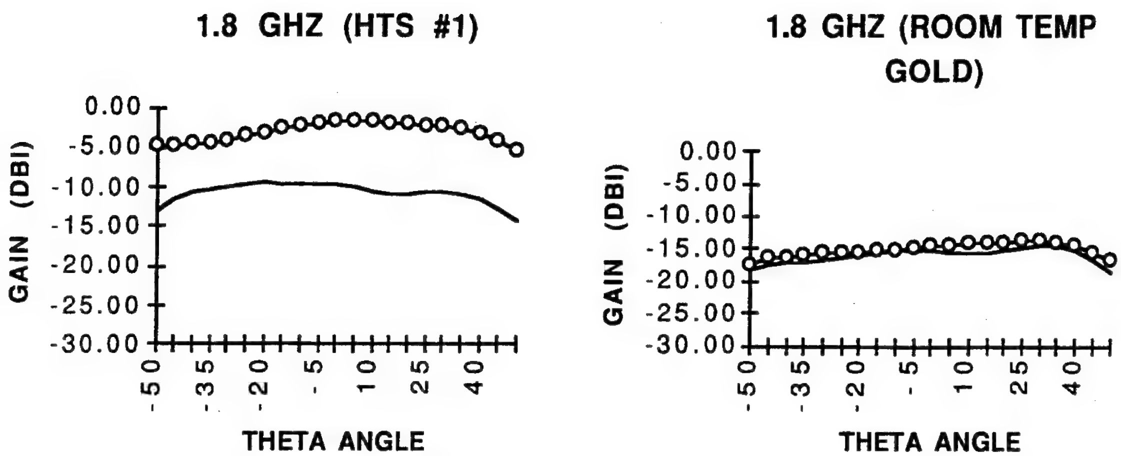


FIGURE 7. (Contd.)

Examination of these patterns shows that the same type improvements gained in the 3-inch Archimedean design are not attained with the modulated arm design. The patterns do not improve noticeably at any specific frequency and, in fact, the gold spiral is better at the high end of the test band than the HTS spiral. This type of geometry has not been used in many applications to my knowledge, and appears to have some basic performance problems.

The analysis of the 2-inch design was not pursued any further because of the poor quality of the patterns attained.

CONCLUSIONS

The test data presented illustrates the advantages that were projected for a HTS electrically small spiral. The gain improvement is quite dramatic down to frequencies a factor of 2 lower in frequency than any other spiral antenna design (7 to 15 dB). This type of frequency extension of spiral antennas has been attempted for the last 20 years, with no success. Only the very low loss of the HTS material makes this type of gain and pattern frequency extension possible. The concept of lower frequency spirals on small airframes or spirals that demand little space on larger airframes is now a reality. Once the cooling issue is resolved, this design will become a very real possibility for application.

REFERENCES

1. Final Report for Contract # N00014-94-C-002, February 1995.

Appendix A

3- AND 2-INCH-DIAMETER SPIRAL ANTENNA PICTURES

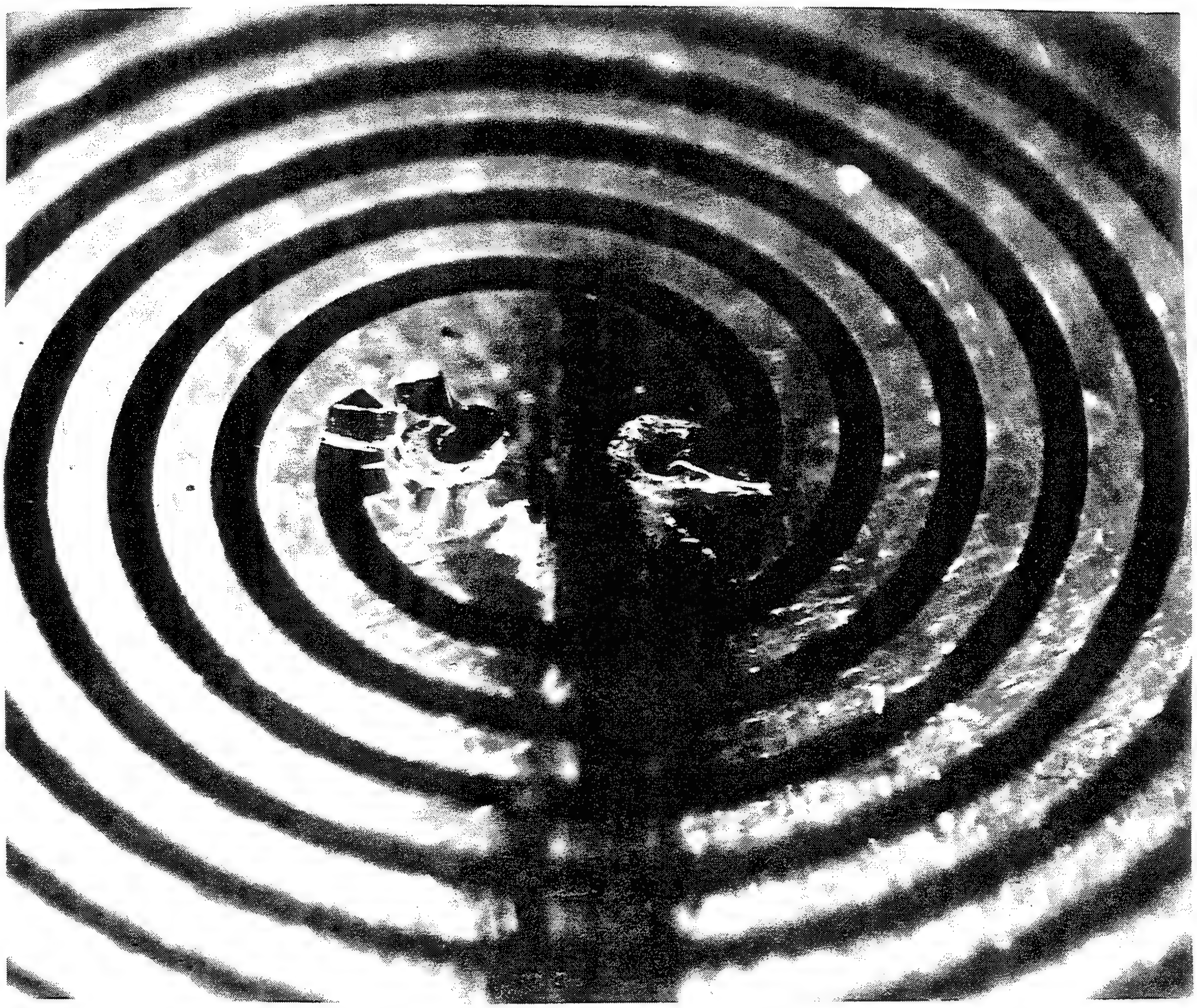


FIGURE A-1. Close-Up of Spiral Center Feed.

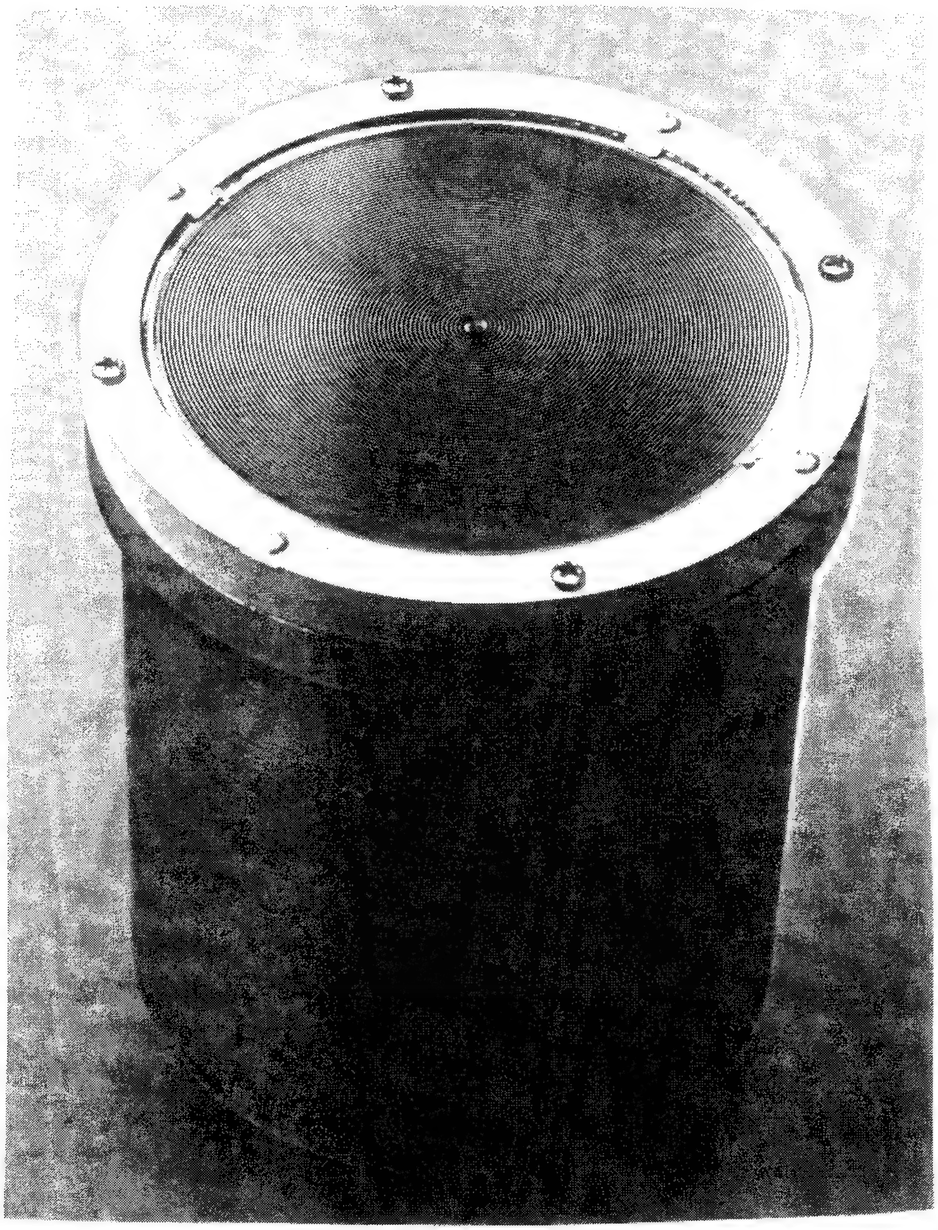


FIGURE A-2. 3-Inch-Diameter Archimedean Spiral.

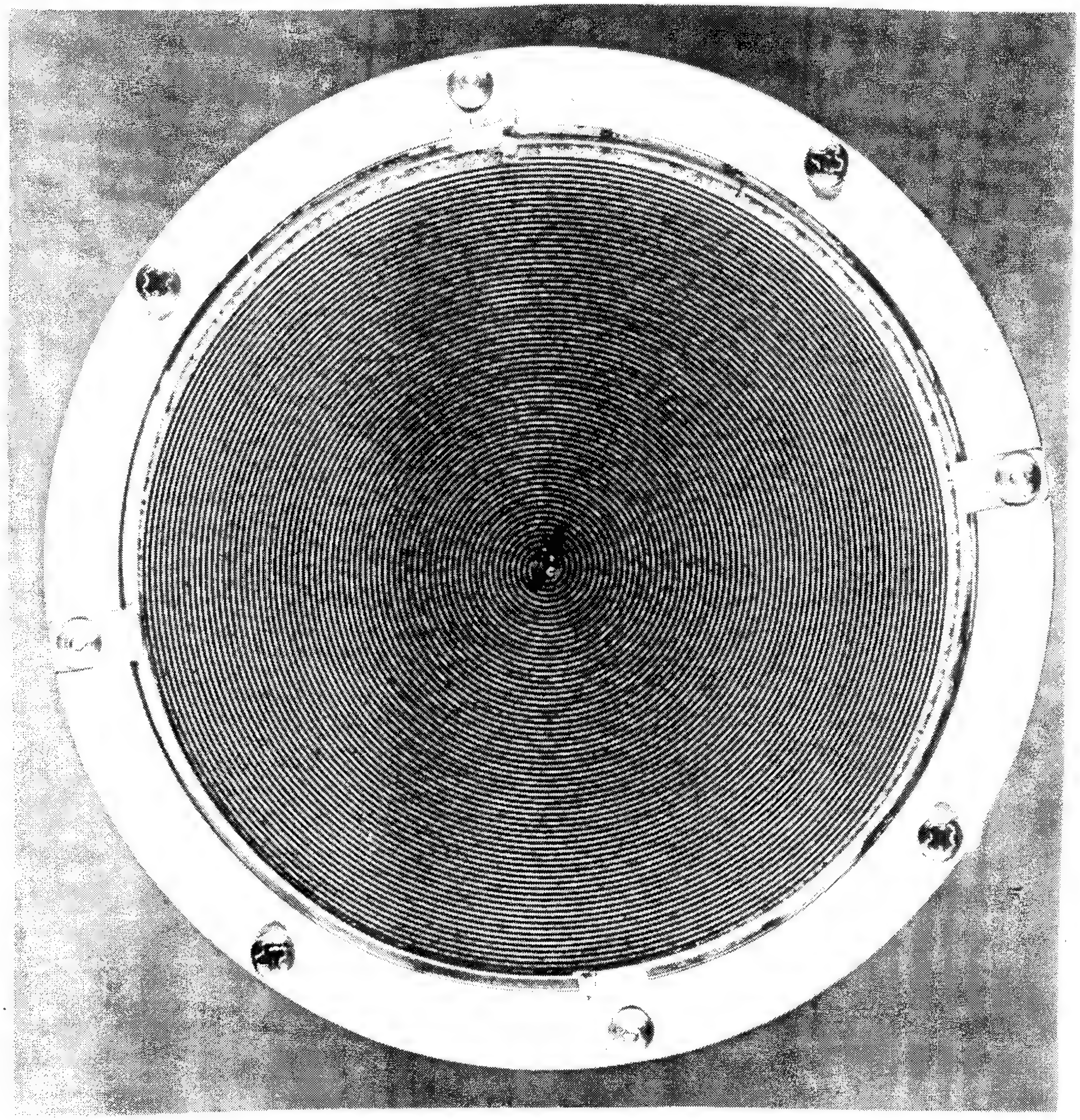


FIGURE A-3. 3-Inch-Diameter Archimedean Spiral.

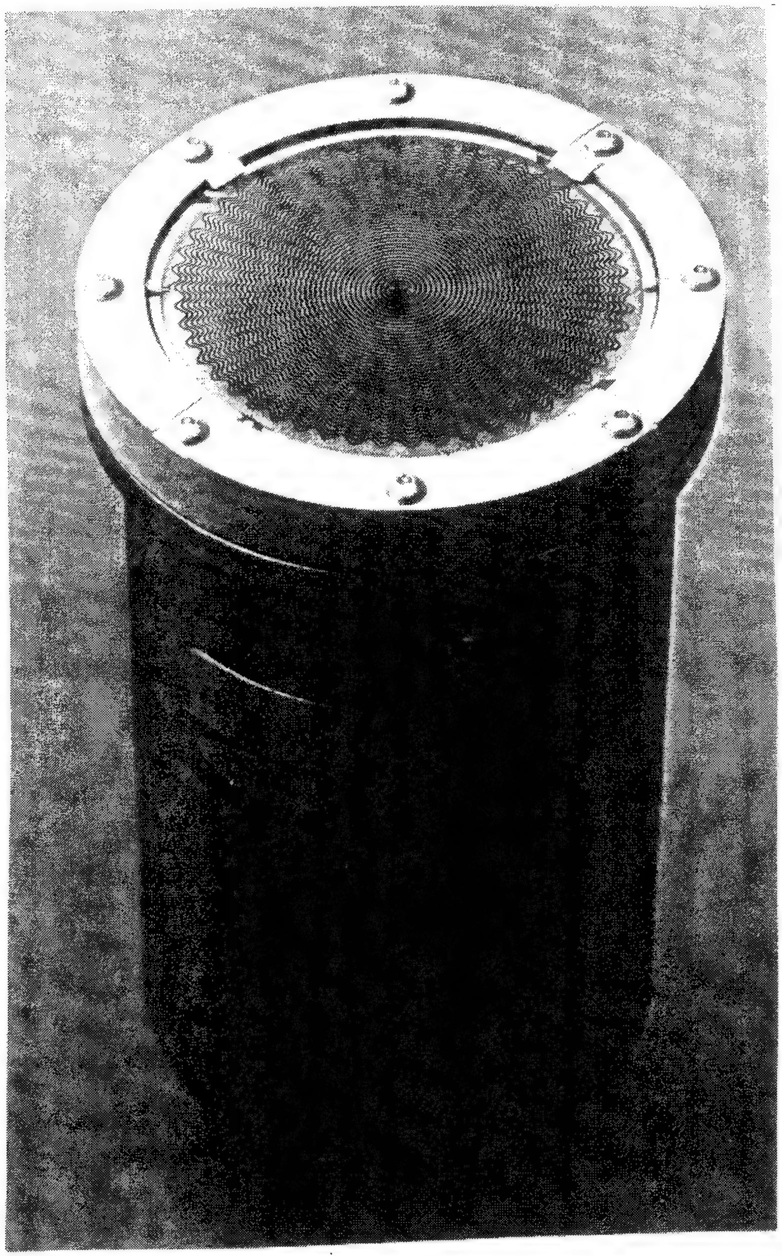


FIGURE A-4. 2-Inch-Diameter Modulated Arm Spiral.

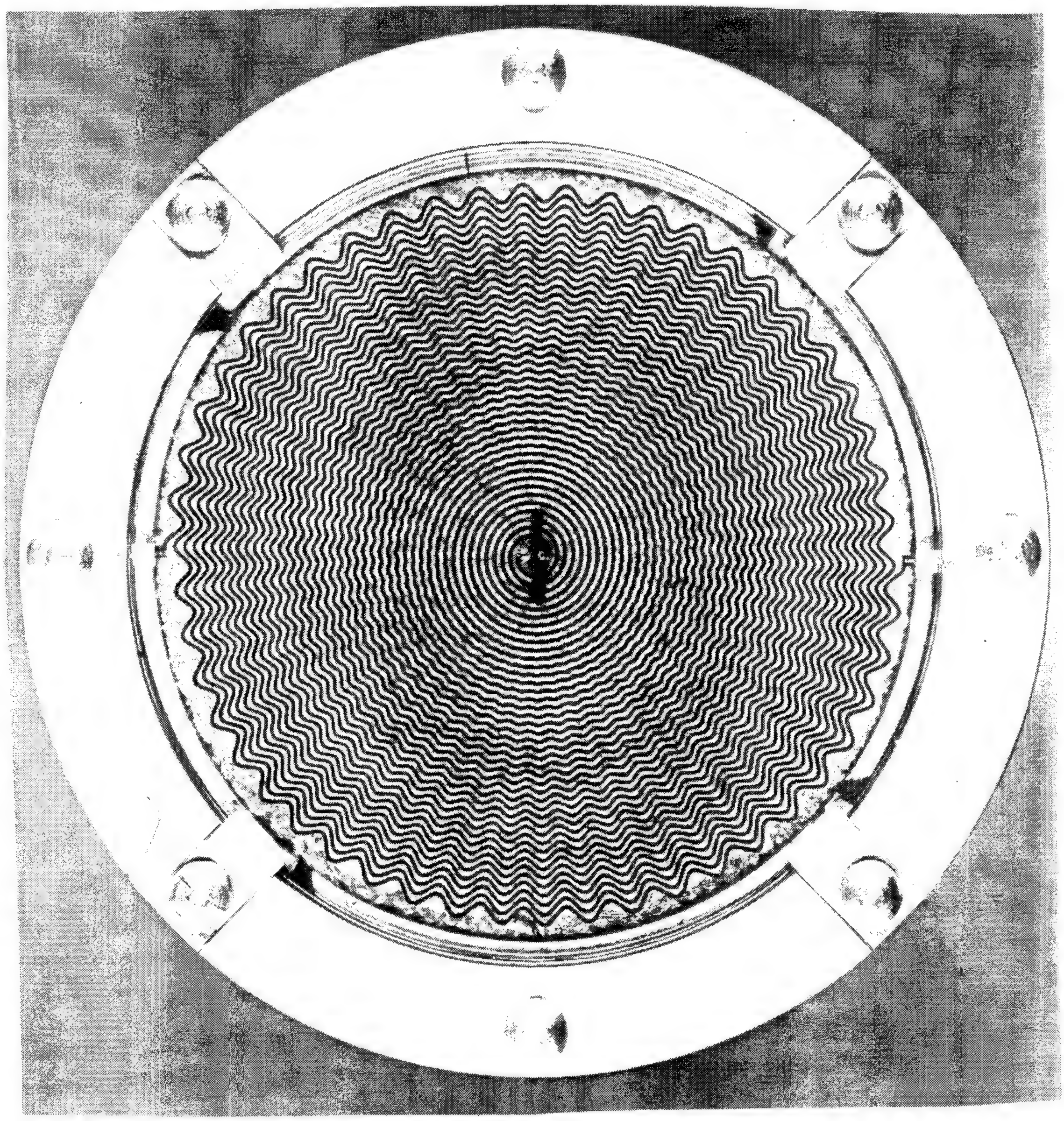


FIGURE A-5. 2-Inch-Diameter Modulated Arm Spiral.

Appendix B

POLAR PATTERN PLOTS FOR 3-INCH-DIAMETER SPIRALS WITH UNTERMINATED SPIRAL ARMS (SUPERCONDUCTIVE AND GOLD AT 77 DEGREES KELVIN)

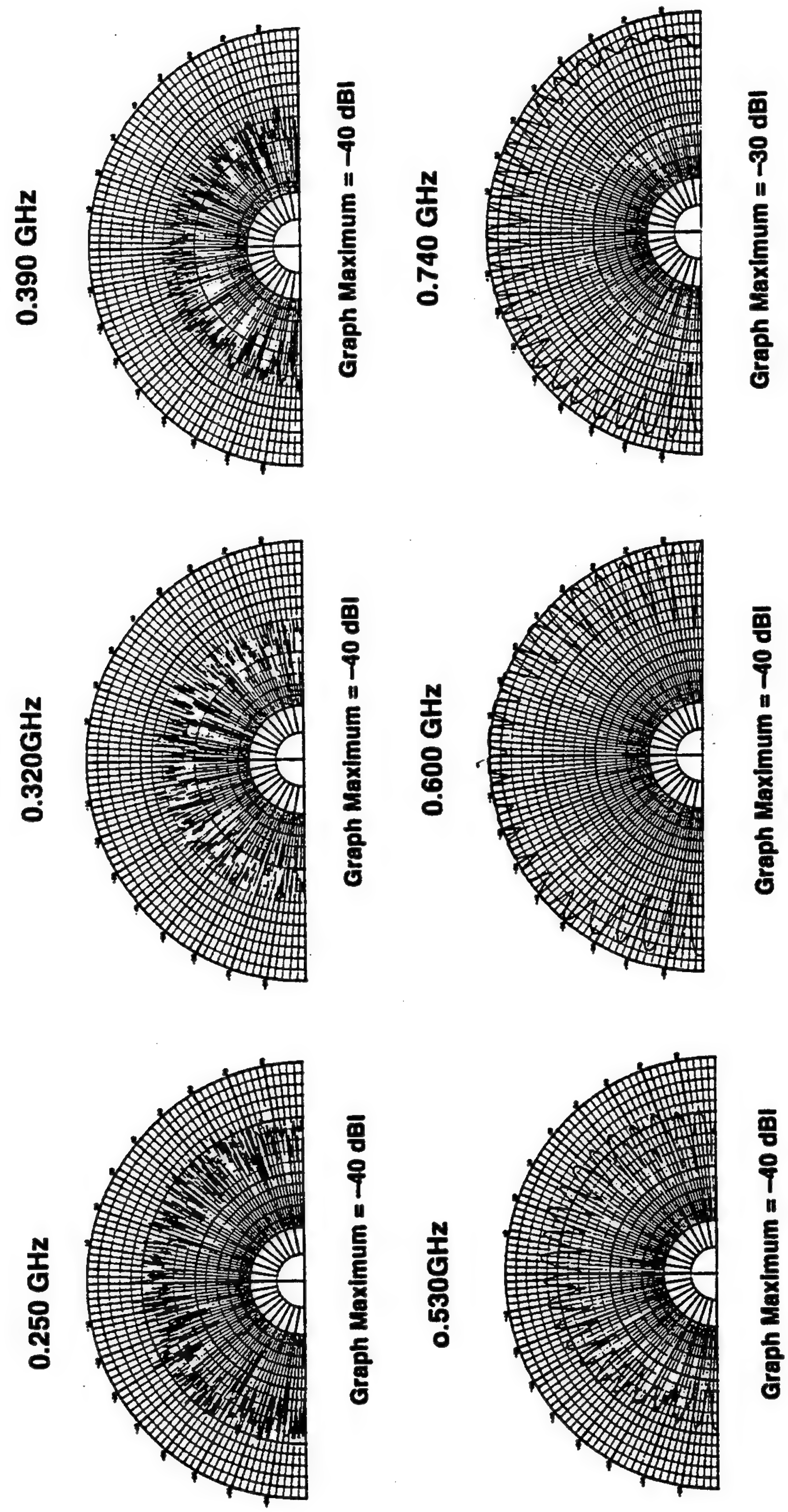


FIGURE B-1. Gold Spiral at 77 Degrees Kelvin.

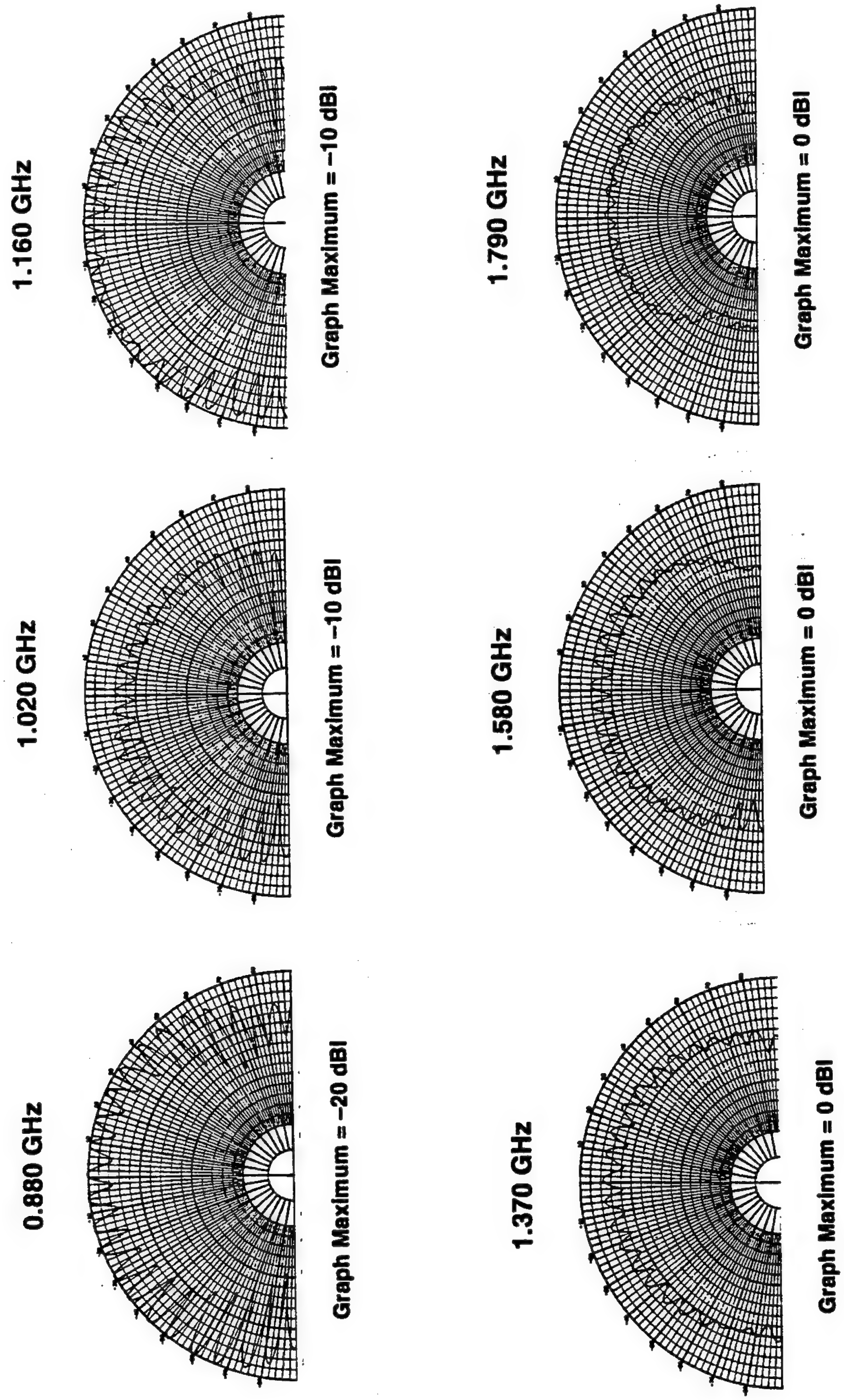


FIGURE B-2. Gold Spiral at 77 Degrees Kelvin.

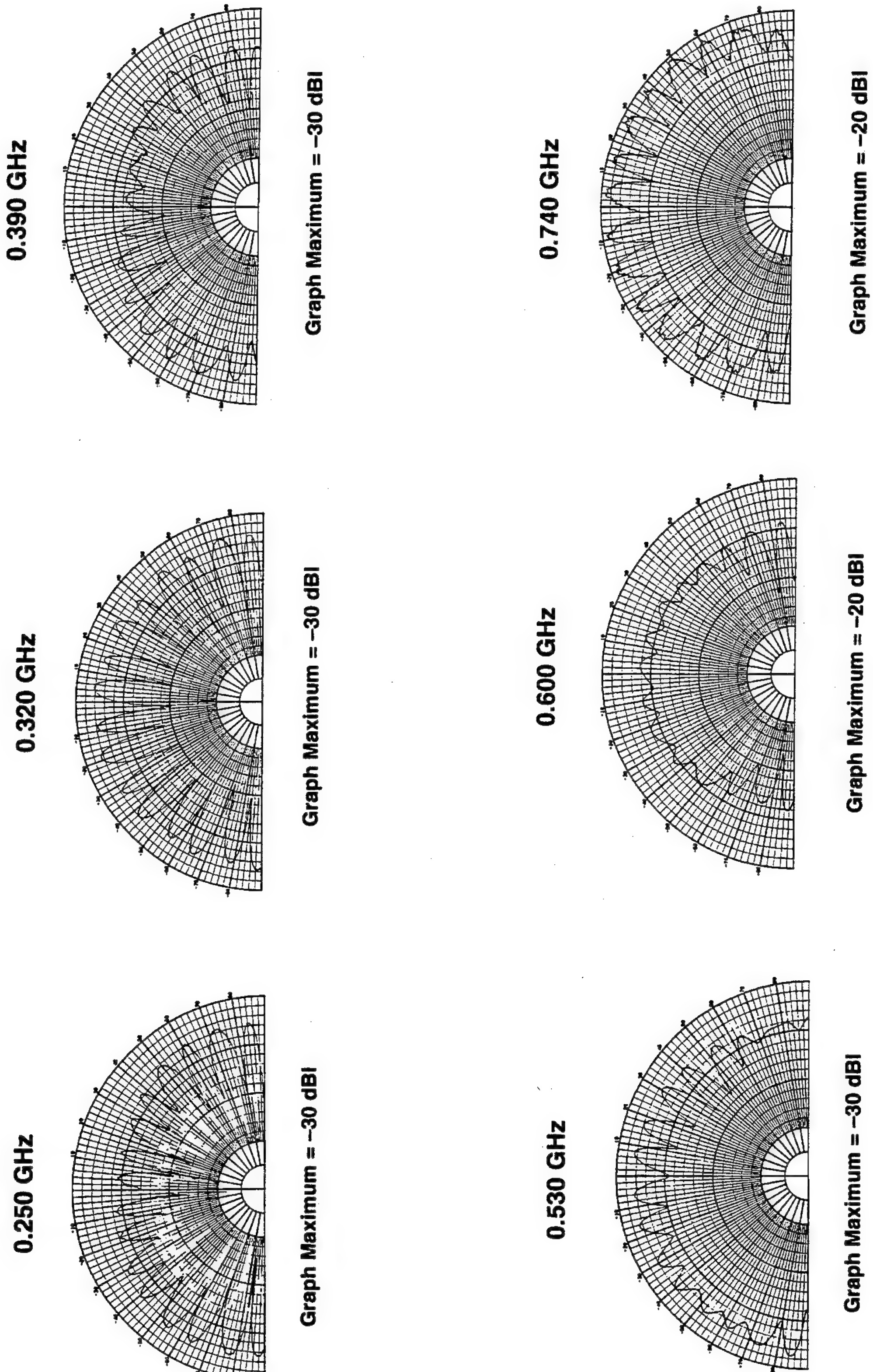


FIGURE B-3. HTS Spiral.

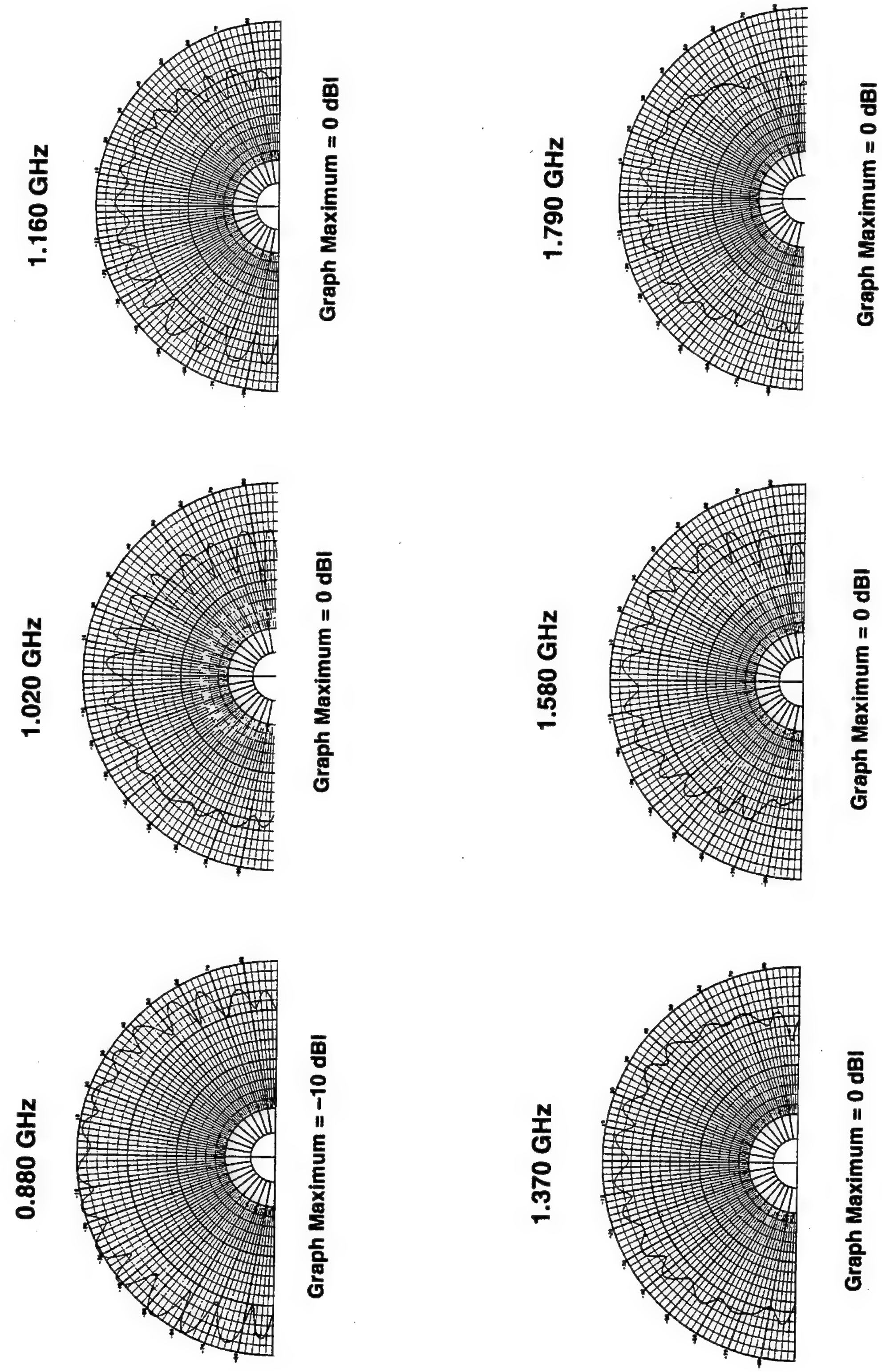


FIGURE B-4. HTS Spiral.

Appendix C

REPORTED AEL INDUSTRIES SPIRAL BALUN LOSS MEASUREMENT

The baluns were tested on the HP8510B in the configuration shown on the block diagram. The Time Domain capabilities and the Gating function were used to gate out all but the feed point, the impedance taper end of the balun. The resulting gated return loss shows two times the loss attributed to the feed network from the calibration reference plane to the feed point. These loss values were then used to adjust the gain values.

Data shows return loss without and with gating turned on. Markers #1 and #2 mark 240 MHz and 2.0 GHz, respectively.

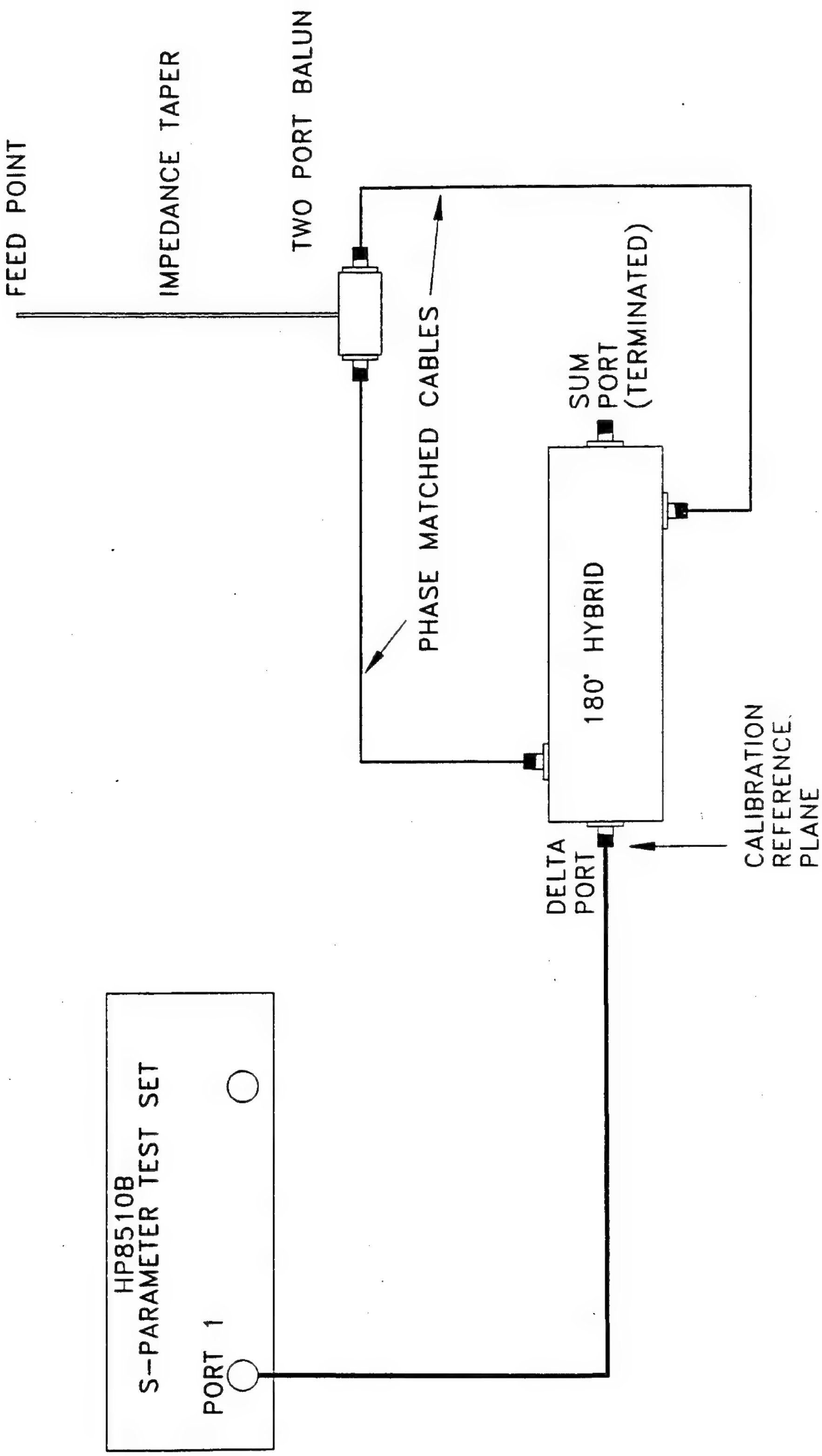


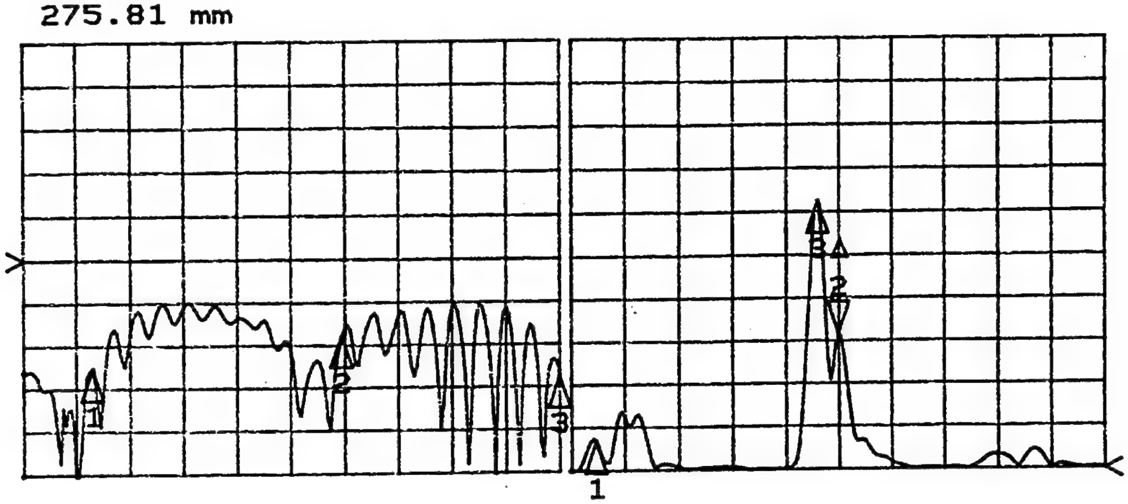
FIGURE C-1. Block Diagram of AEL Antenna Balun Loss Test.

S11 log MAG
REF 0.0 dB
Δ 5.0 dB/
2 4.9224 dB

S11 LINEAR
REF 0.0 Units
2 50.0 mUnits/
∇ −154.65 mU.

3.0IN AU HYBRID+CABLES AMBIENT

C
MARKER 2−3
920.0 ps
275.81 mm



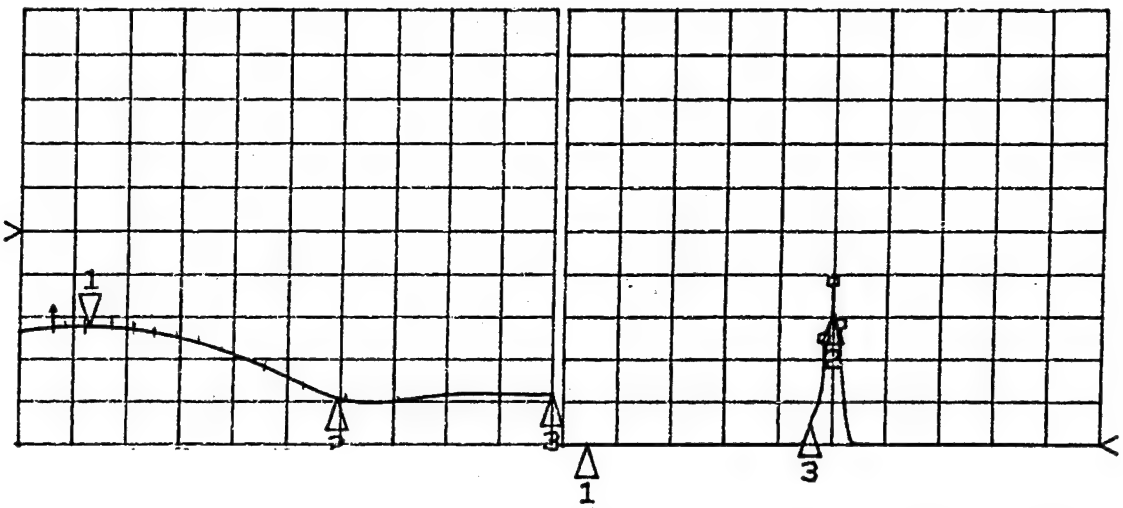
START 0.100000000 GHz START −1.0 ns
STOP 2.500000000 GHz STOP 22.0 ns

S11 log MAG
REF 0.0 dB
1 5.0 dB/
▽ -11.069 dB

S11 LINEAR
REF 0.0 Units
Δ 50.0 mUnits/
1 34.582 µU.

3.0IN AU HYBRID+CABLES AMBIENT

C
GATE SPAN
747.0 ps
G 223.95 mm

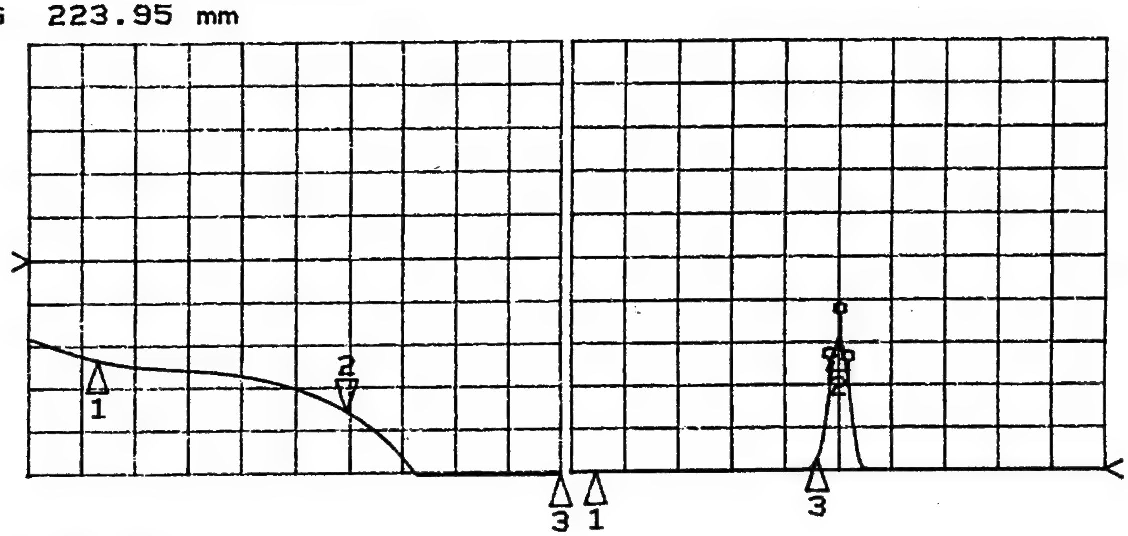


GATE GROUND FEED POINT OF SPIRAL

START 0.100000000 GHz START -1.0 ns
STOP 2.500000000 GHz STOP 22.0 ns

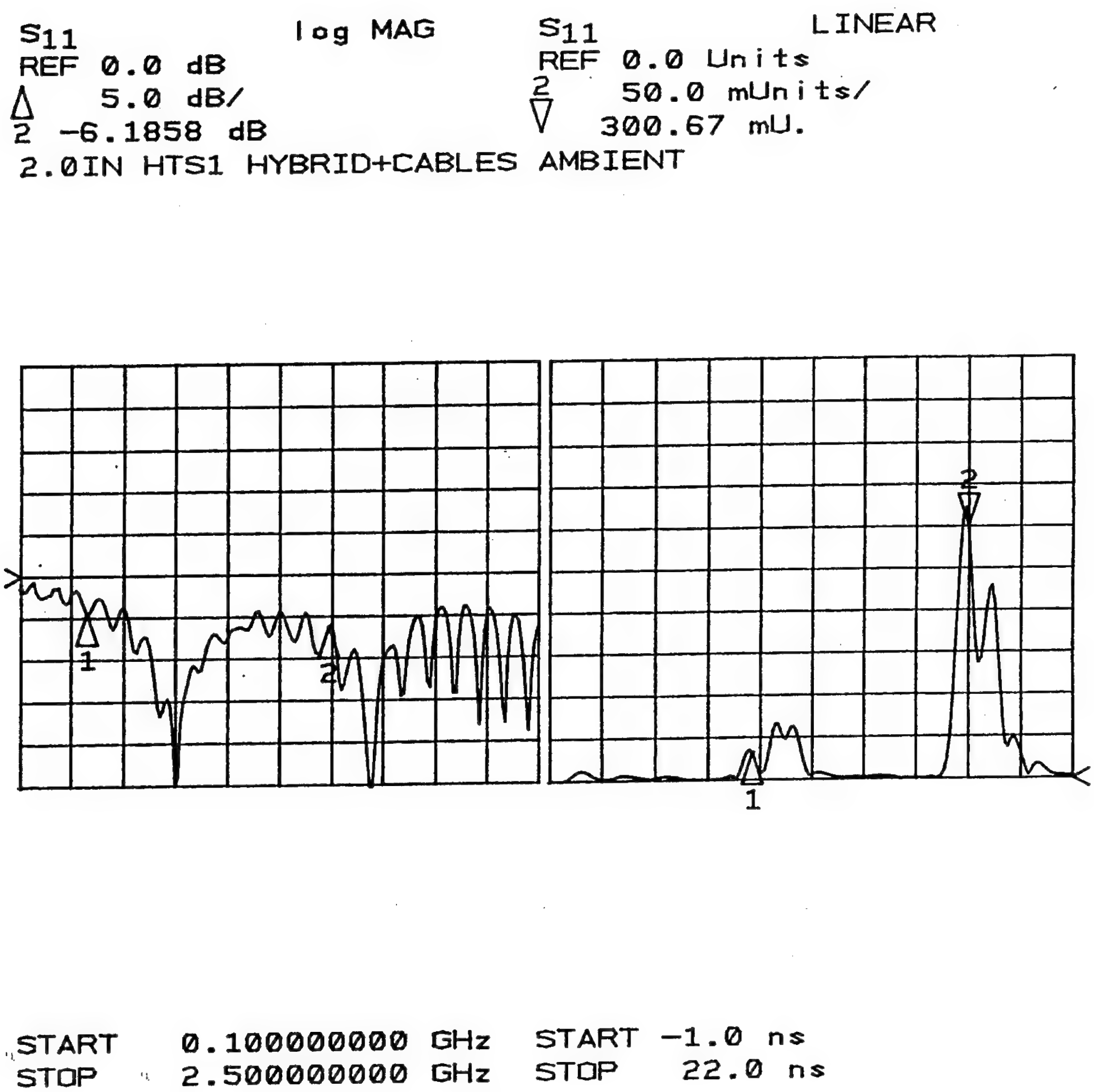
S_{11} log MAG S_{11} LINEAR
REF 0.0 dB REF 0.0 Units
2 ▽ 5.0 dB/ △ 50.0 mUnits/
−17.814 dB 2 153.86 mU.
3.0IN HTS HYBRID+CABLES AMBIENT

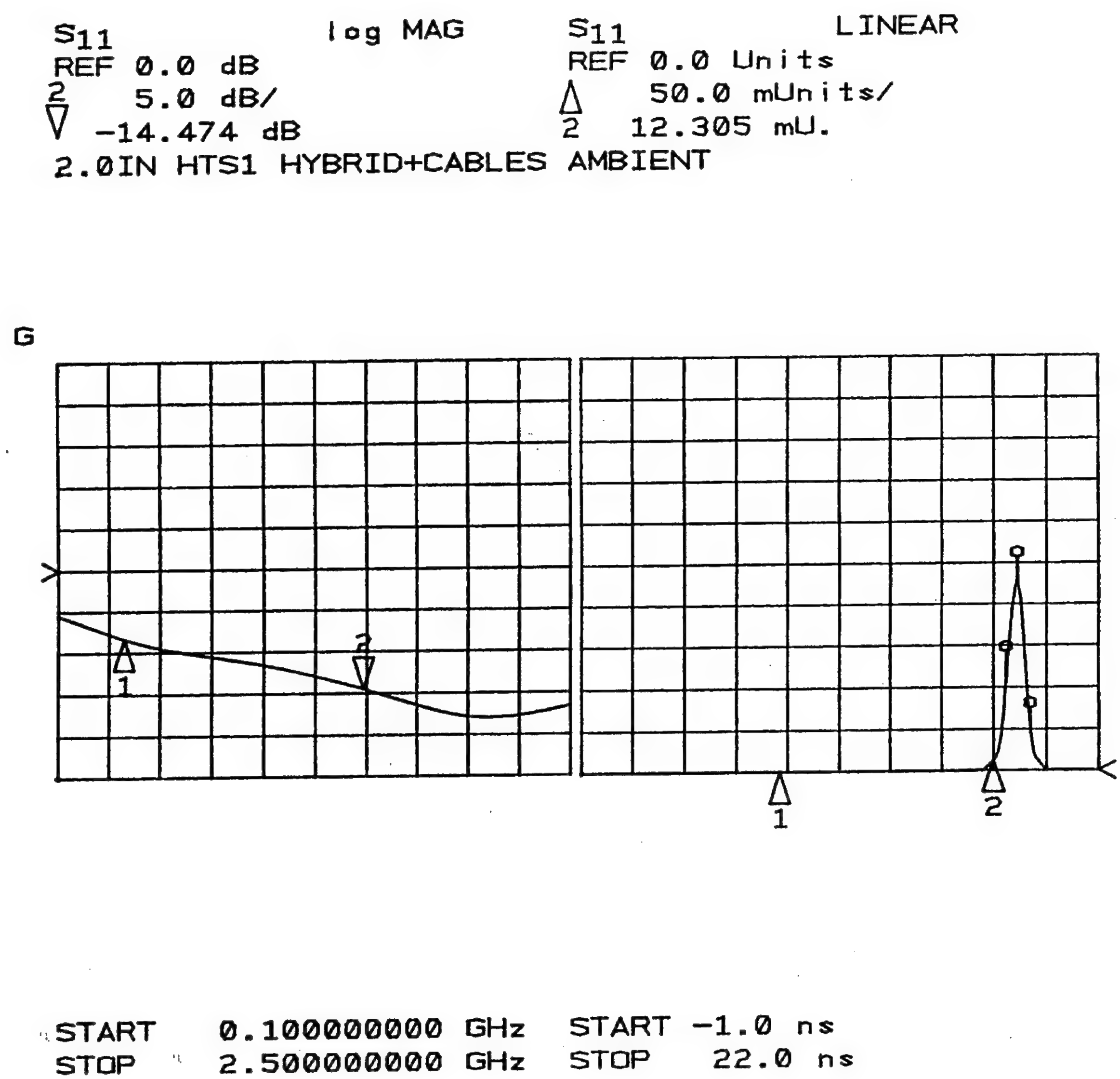
C
GATE SPAN
747.0 ps
G 223.95 mm



#1 - 250 MHz
#2 - 2.0 GHz

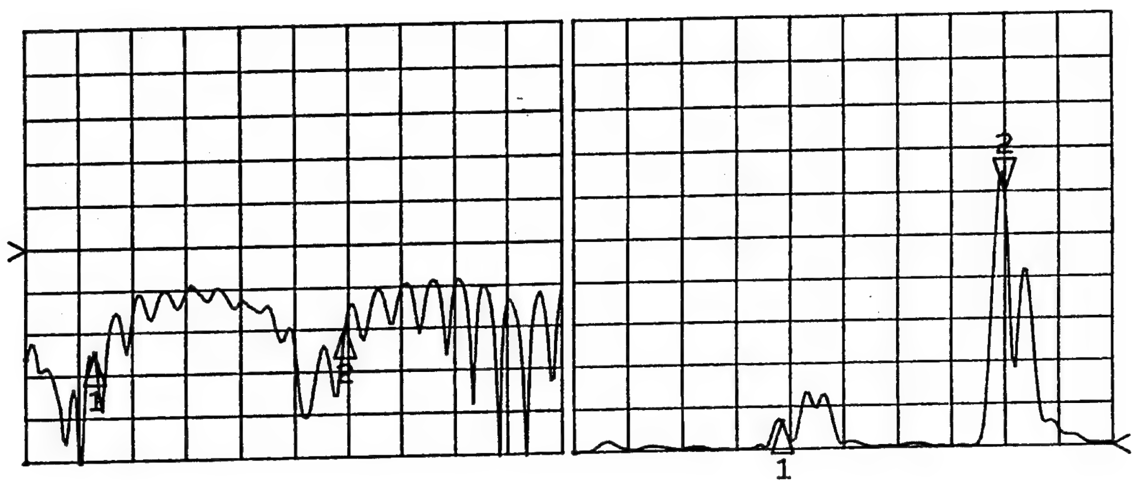
START 0.100000000 GHz START −1.0 ns
STOP 2.500000000 GHz STOP 22.0 ns


S11 log MAG
REF 0.0 dB
Δ 5.0 dB/
2 -6.1858 dB
S11 LINEAR
REF 0.0 Units
2 50.0 mUnits/
▽ 300.67 mU.
2.0IN HTS1 HYBRID+CABLES AMBIENT
1
2
2
1
START 0.100000000 GHz
STOP 2.500000000 GHz
START -1.0 ns
STOP 22.0 ns


S11 log MAG
REF 0.0 dB
2 5.0 dB/
▽ -14.474 dB
S11 LINEAR
REF 0.0 Units
△ 50.0 mUnits/
2 12.305 mU.
2.0IN HTS1 HYBRID+CABLES AMBIENT
G
1
2
1
2
START 0.100000000 GHz
STOP 2.500000000 GHz
START -1.0 ns
STOP 22.0 ns

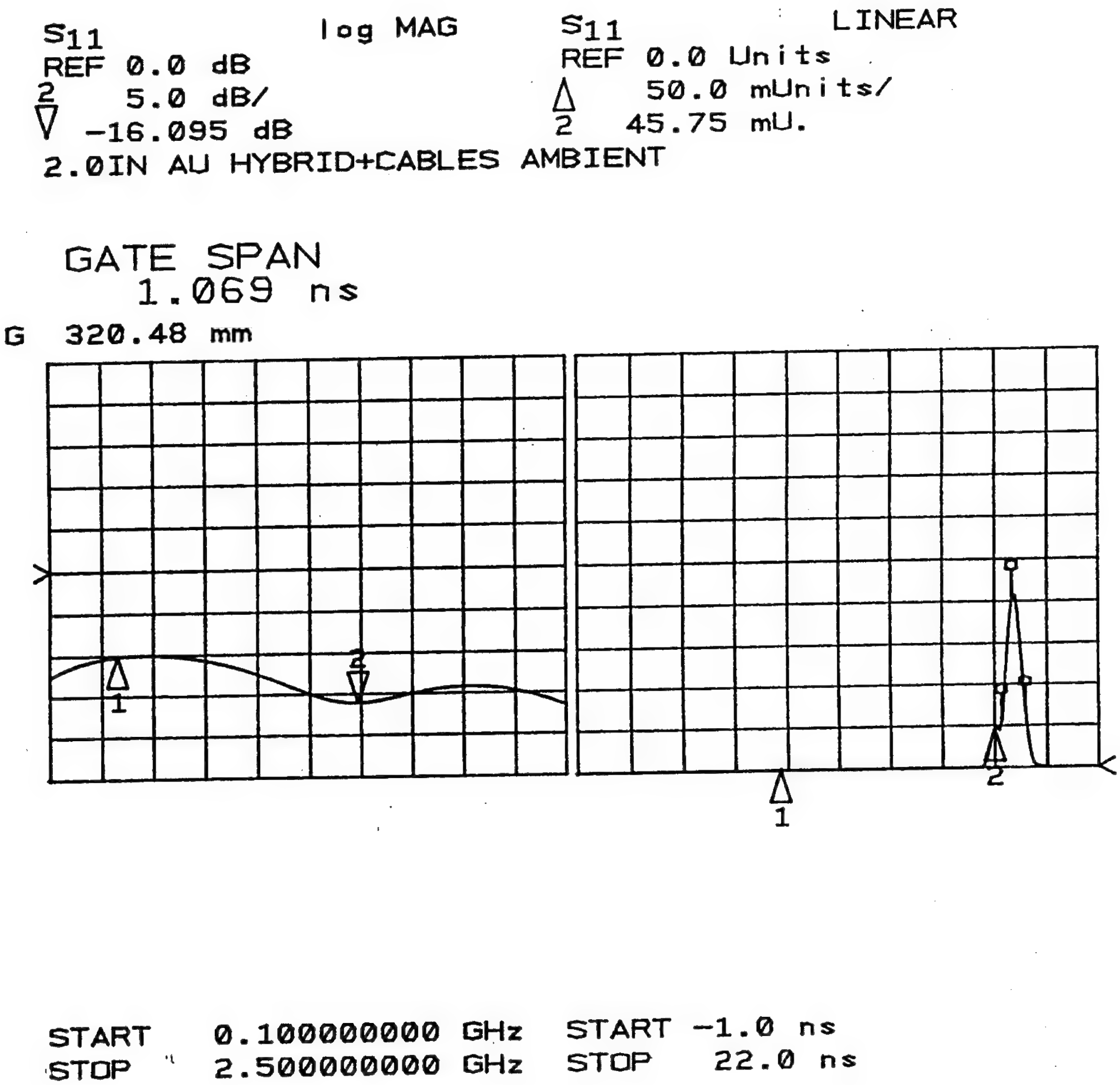
S11 log MAG
REF 0.0 dB
△ 5.0 dB/
2 −9.6436 dB
2.0IN AU HYBRID+CABLES AMBIENT

S11 LINEAR
REF 0.0 Units
2 50.0 mUnits/
▽ 299.13 mU.



START 0.100000000 GHz
STOP 2.500000000 GHz

START −1.0 ns
STOP 22.0 ns


S11 log MAG
REF 0.0 dB
2 5.0 dB/
-16.095 dB
S11 LINEAR
REF 0.0 Units
50.0 mUnits/
2 45.75 mU.
2.0IN AU HYBRID+CABLES AMBIENT
GATE SPAN
1.069 ns
G 320.48 mm
1
2
1
2
START 0.100000000 GHz
STOP 2.500000000 GHz
START -1.0 ns
STOP 22.0 ns

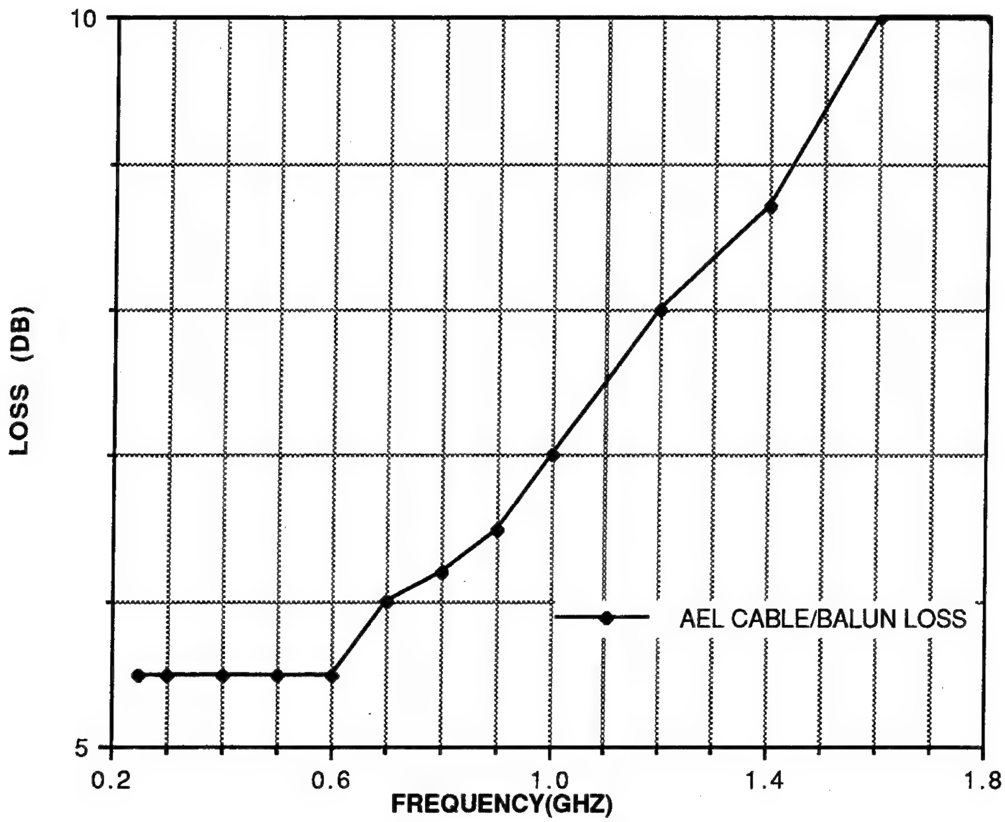


FIGURE C-2. Reported Loss of AEL Industries Spiral Balun.

Appendix D

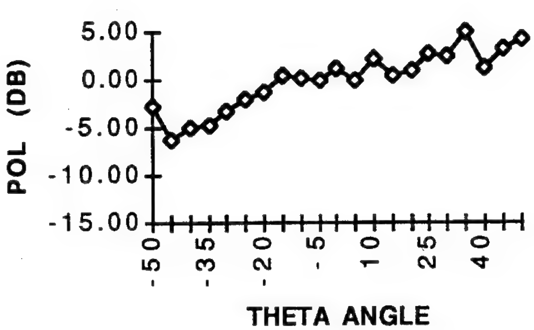
3-INCH-DIAMETER HTS SPIRAL TEST ANTENNA ORIENTATION 1 & 2 COMPARISONS

In order to look for antenna chamber induced errors, particularly at the low frequencies tested, the antenna test plan required the tests of vertical and horizontal source antenna positions to be done with the spirals at two different positions. One would be defined as the reference position and the other was with the spiral at 180 degrees rotation to the reference. This was hoped to enable any chamber induced pattern errors to be found and any mechanical antenna pointing errors to be removed. The reasoning for this is as follows. If there is a skew in the pattern due to a chamber induced error (assuming a perfect antenna), the pattern maximum will be tilted from 0 degrees. If the antenna is then rotated 180 degrees, the pattern will still be tilted from 0 degrees by the same amount. This is then the chamber induced error.

If the antenna has a tilted beam maximum due to imperfections or there is a mechanical pointing error in the mounting hardware, the antenna beam will simply rotate 180 degrees when the antenna is rotated. Thus, the chamber induced errors can be found by looking at the change in the beam pointing when the antenna is rotated. Averaging the two patterns will take out the mechanical pointing errors.

PATTERN COMPARISONS FOR TWO OPPOSITE ROTATIONAL POSITIONS

ORIENTATION 1
RIGHT TO LEFT CIRCULAR POLARIZATION-0.25 GHZ



ORIENTATION 2
RIGHT TO LEFT CIRCULAR POLARIZATION-0.25 GHZ

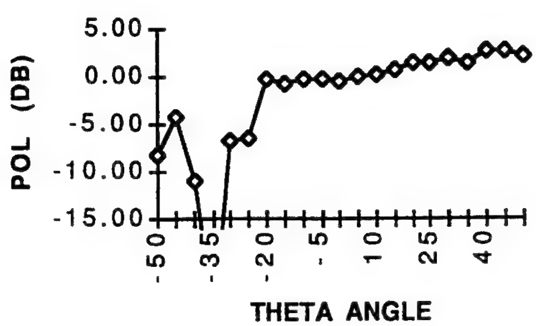


FIGURE D-1. 3-Inch-Diameter Archimedean Spiral: HTSC Orientation 1 to 2.

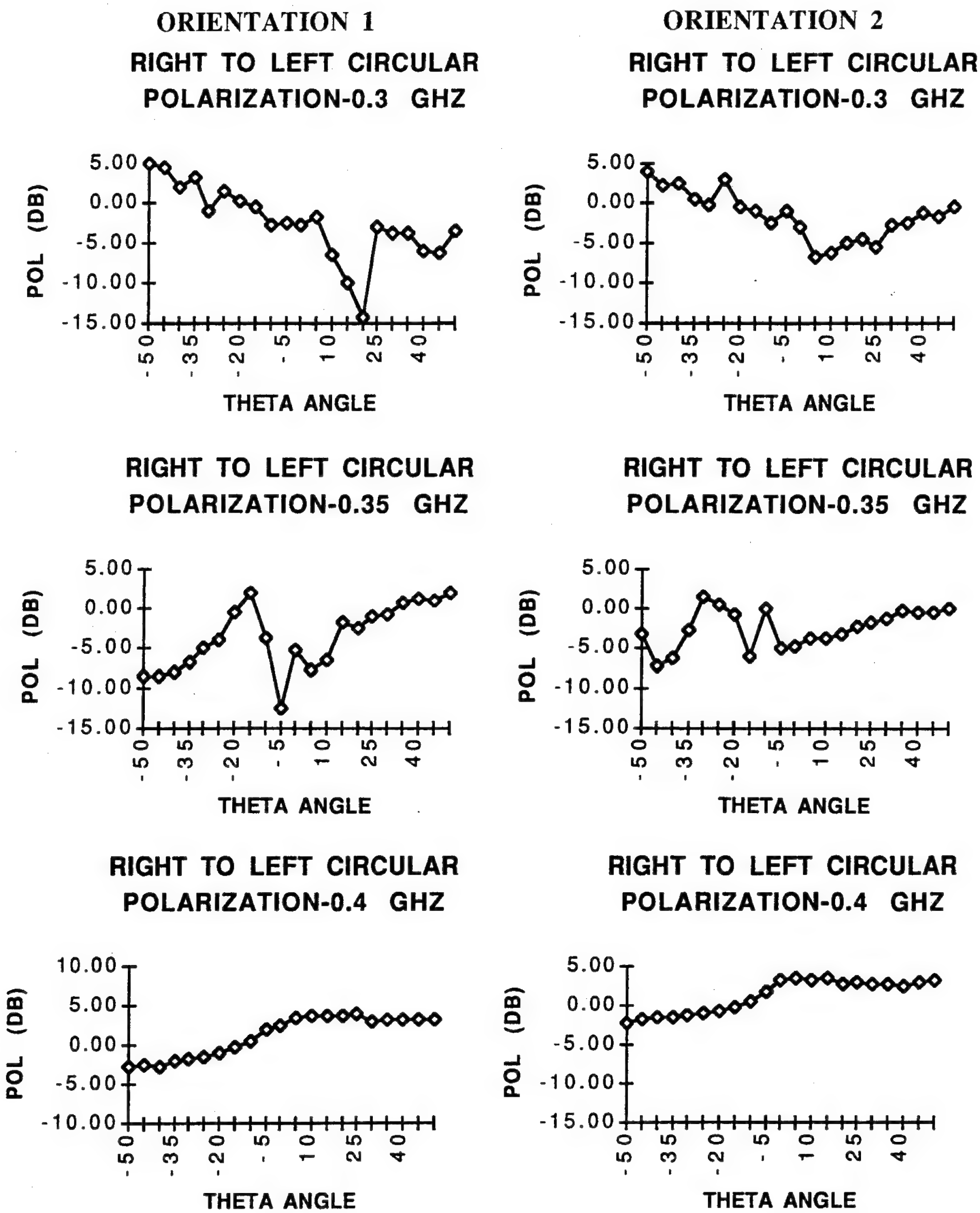
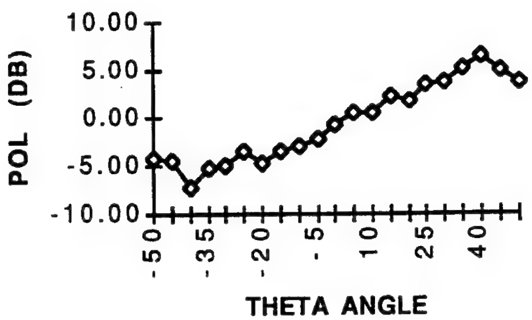


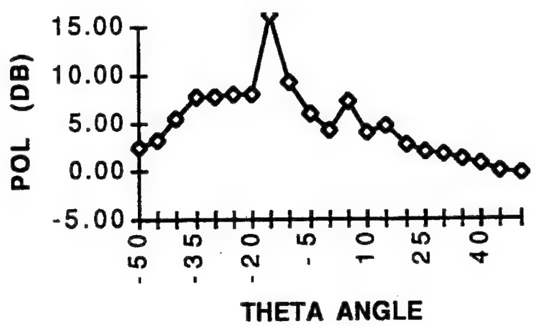
FIGURE D-1. (Contd.)

ORIENTATION 1

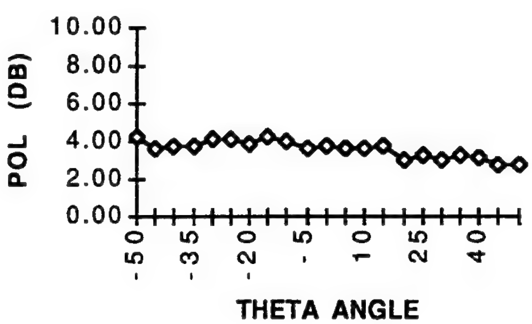
RIGHT TO LEFT CIRCULAR POLARIZATION- .45 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.5 GHZ

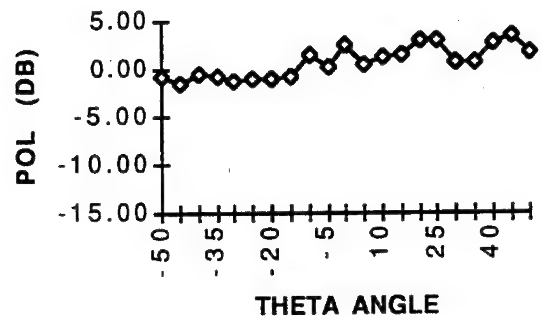


RIGHT TO LEFT CIRCULAR POLARIZATION-0.6 GHZ

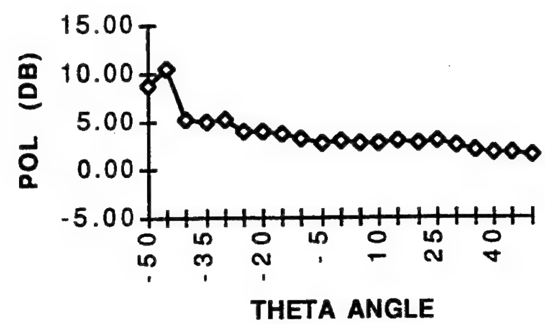


ORIENTATION 2

RIGHT TO LEFT CIRCULAR POLARIZATION-0.45 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.5 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.6 GHZ

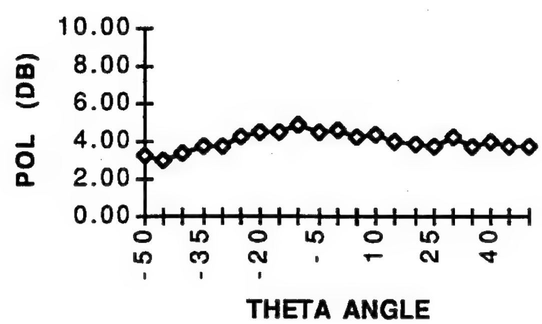
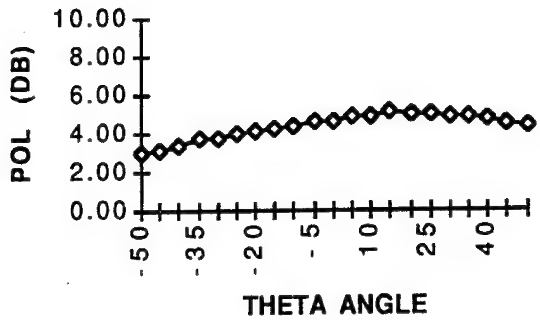


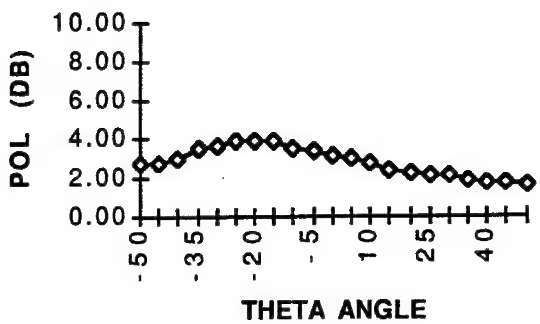
FIGURE D-1. (Contd.)

ORIENTATION 1

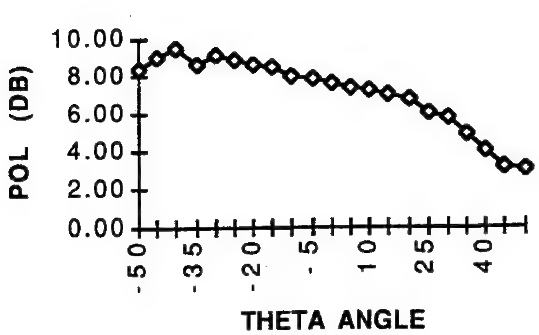
RIGHT TO LEFT CIRCULAR POLARIZATION-0.7 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.8 GHZ

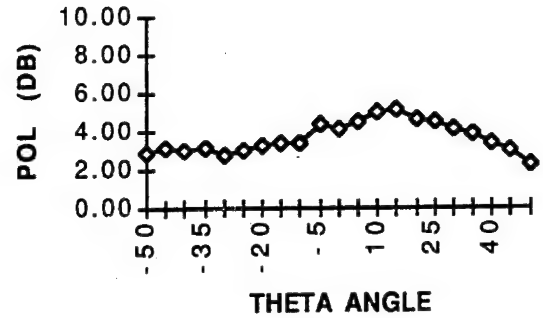


RIGHT TO LEFT CIRCULAR POLARIZATION-0.9 GHZ

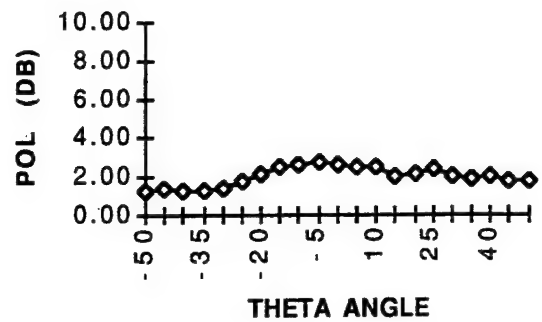


ORIENTATION 2

RIGHT TO LEFT CIRCULAR POLARIZATION-0.7 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.8 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-0.9 GHZ

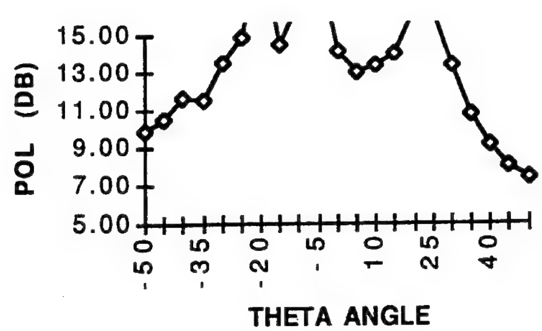
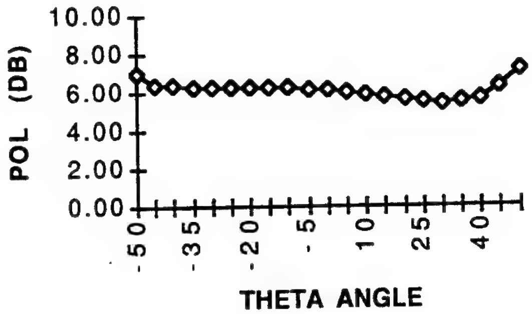


FIGURE D-1. (Contd.)

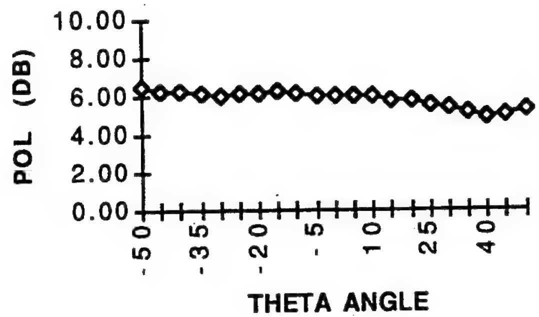
ORIENTATION 1

RIGHT TO LEFT CIRCULAR POLARIZATION-1 GHZ

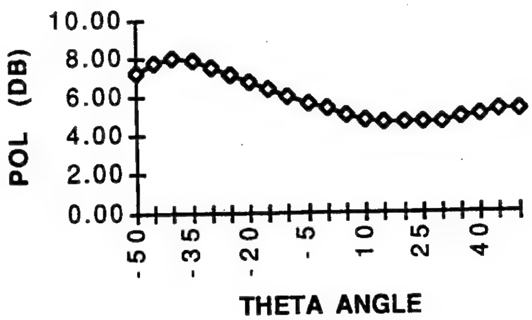


ORIENTATION 2

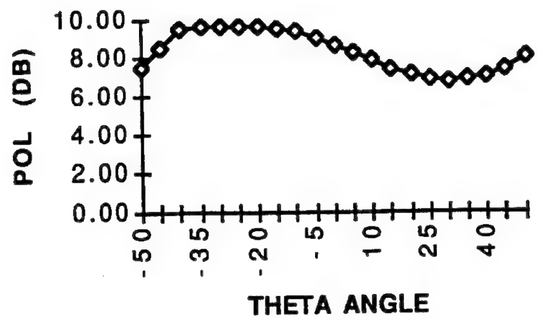
RIGHT TO LEFT CIRCULAR POLARIZATION-1 GHZ



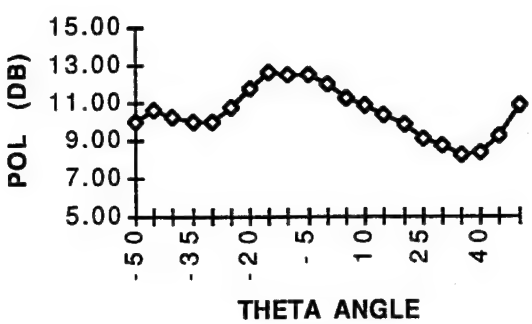
RIGHT TO LEFT CIRCULAR POLARIZATION-1.2 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.2 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.4 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.4 GHZ

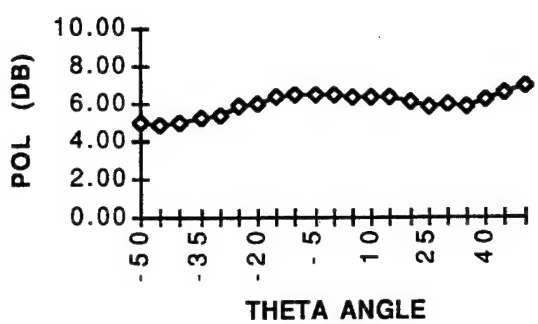
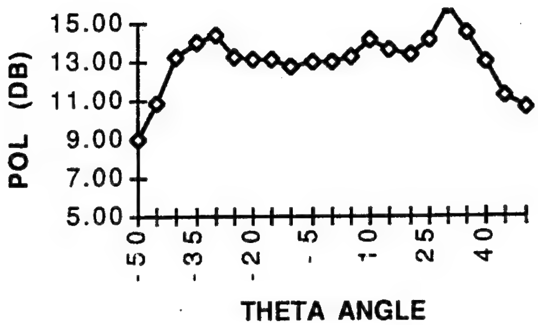


FIGURE D-1. (Contd.)

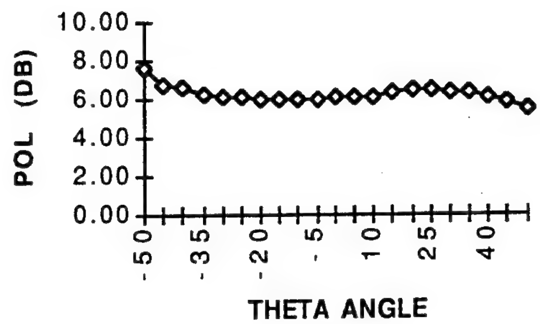
ORIENTATION 1

RIGHT TO LEFT CIRCULAR POLARIZATION-1.6 GHZ

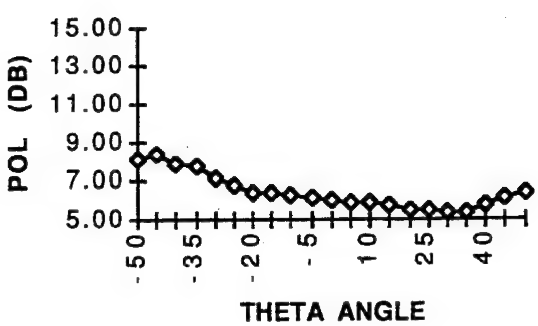


ORIENTATION 2

RIGHT TO LEFT CIRCULAR POLARIZATION-1.6 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.8 GHZ



RIGHT TO LEFT CIRCULAR POLARIZATION-1.8 GHZ

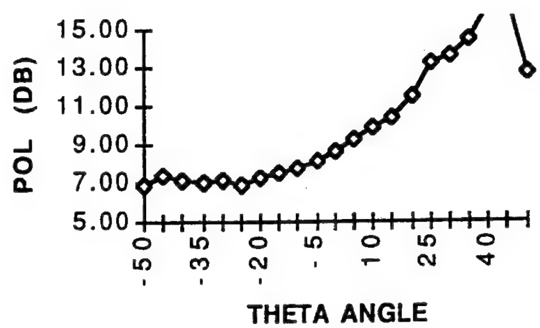


FIGURE D-1. (Contd.)

PATTERN COMPARISONS FOR TWO OPPOSITE ROTATIONAL POSITIONS

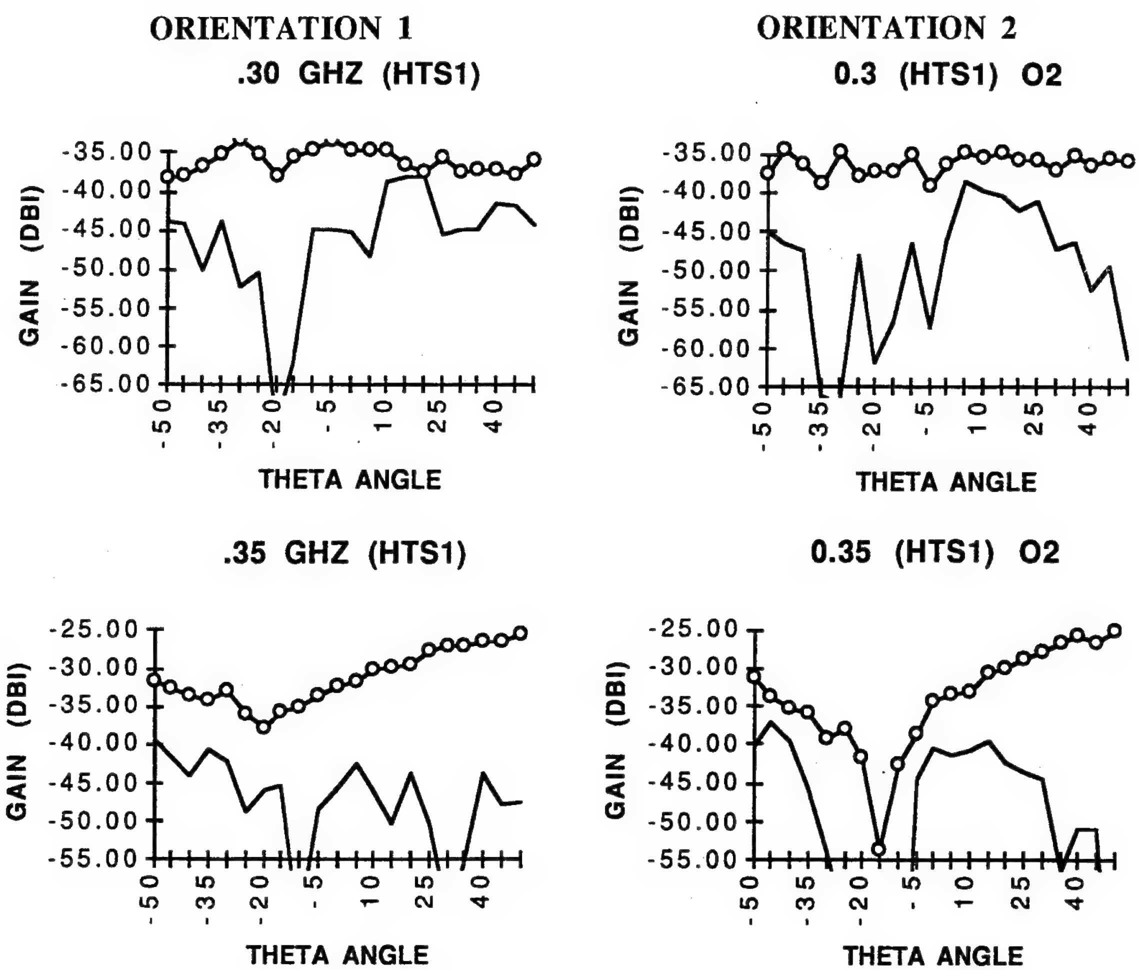
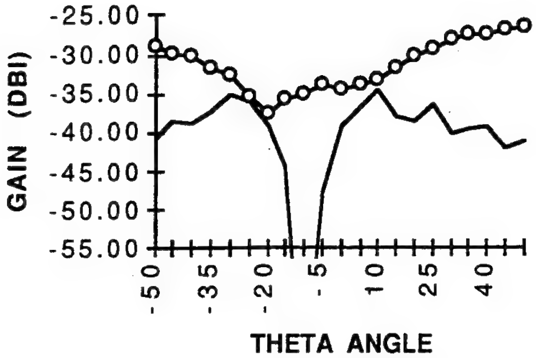


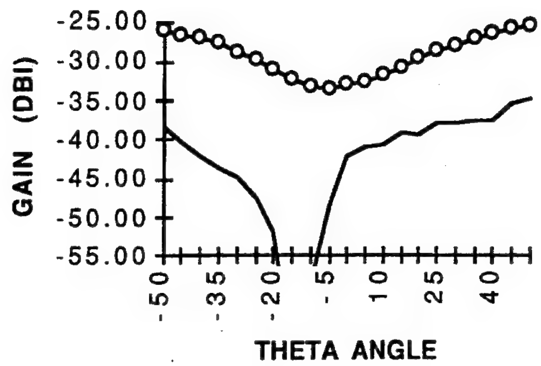
FIGURE D-2. 3-Inch-Diameter Archimedean Spiral: HTSC Orientation 1 to 2.

ORIENTATION 1 | **ORIENTATION 2**

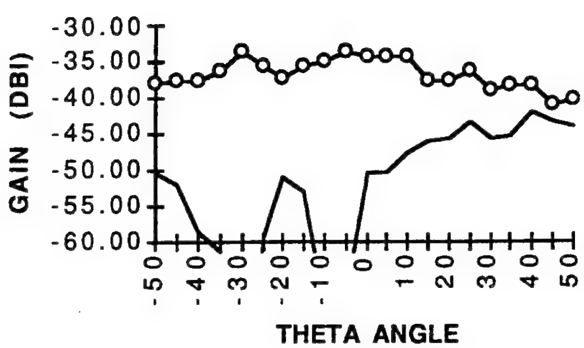
.4 GHZ (HTS1)



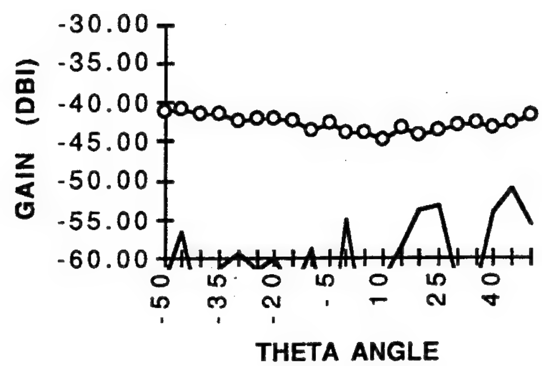
0.4 (HTS1) O2



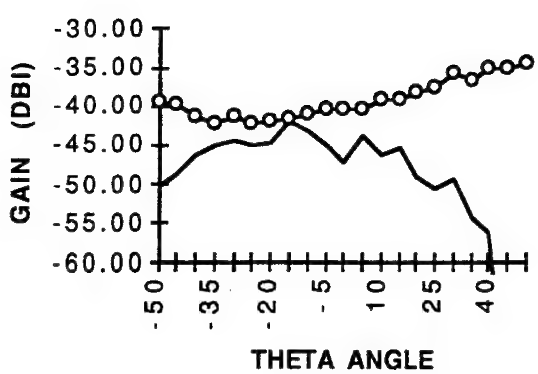
.45 GHZ (HTS1)



0.45 (HTS1) O2



.50 GHZ (HTS1)



0.5 (HTS1) O2

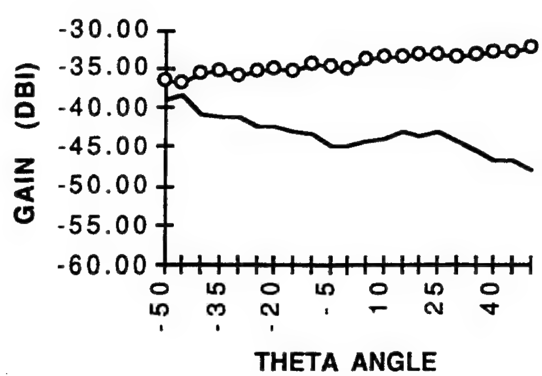


FIGURE D-2. (Contd.)

ORIENTATION 1 **ORIENTATION 2**

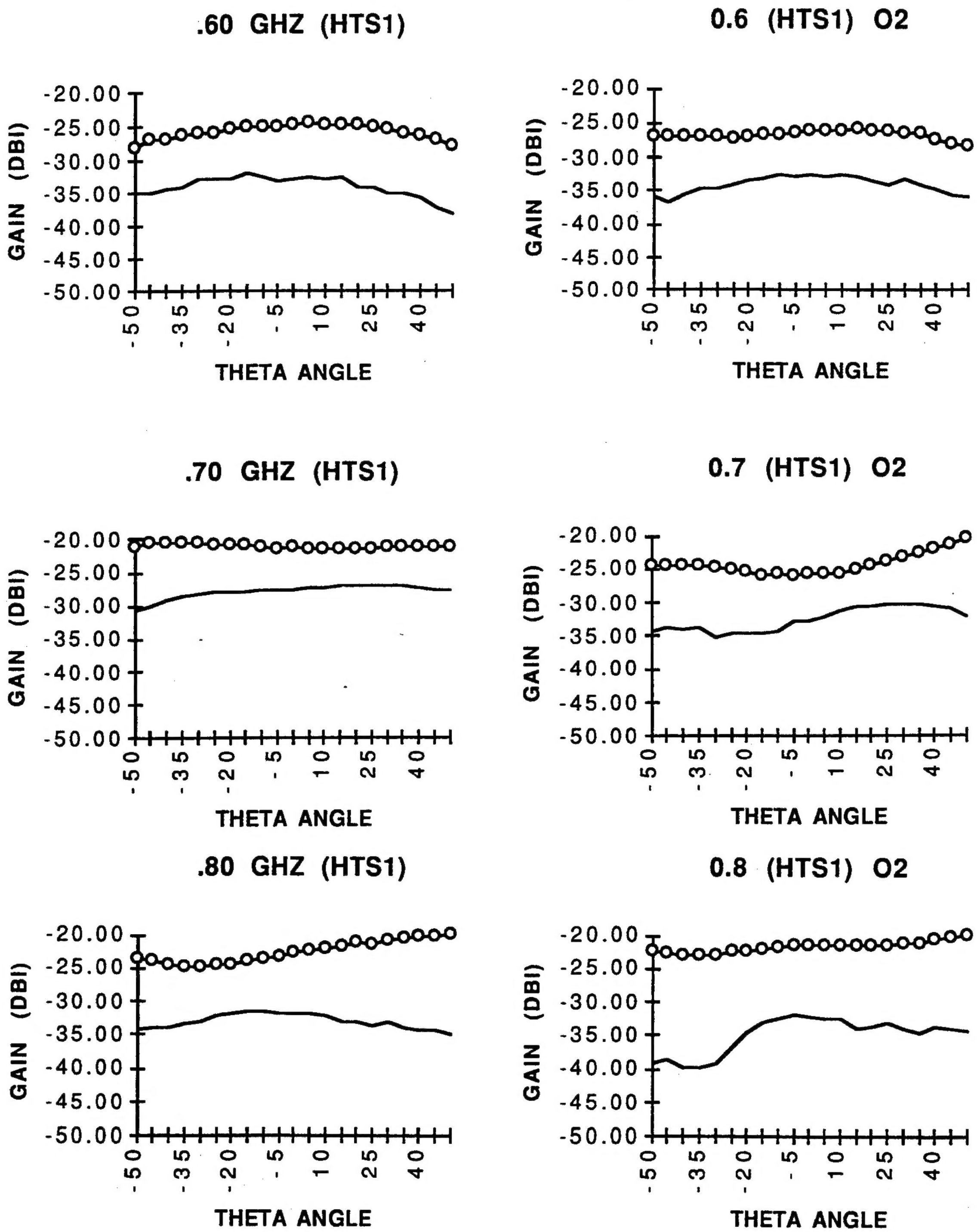


FIGURE D-2. (Contd.)

ORIENTATION 1 **ORIENTATION 2**

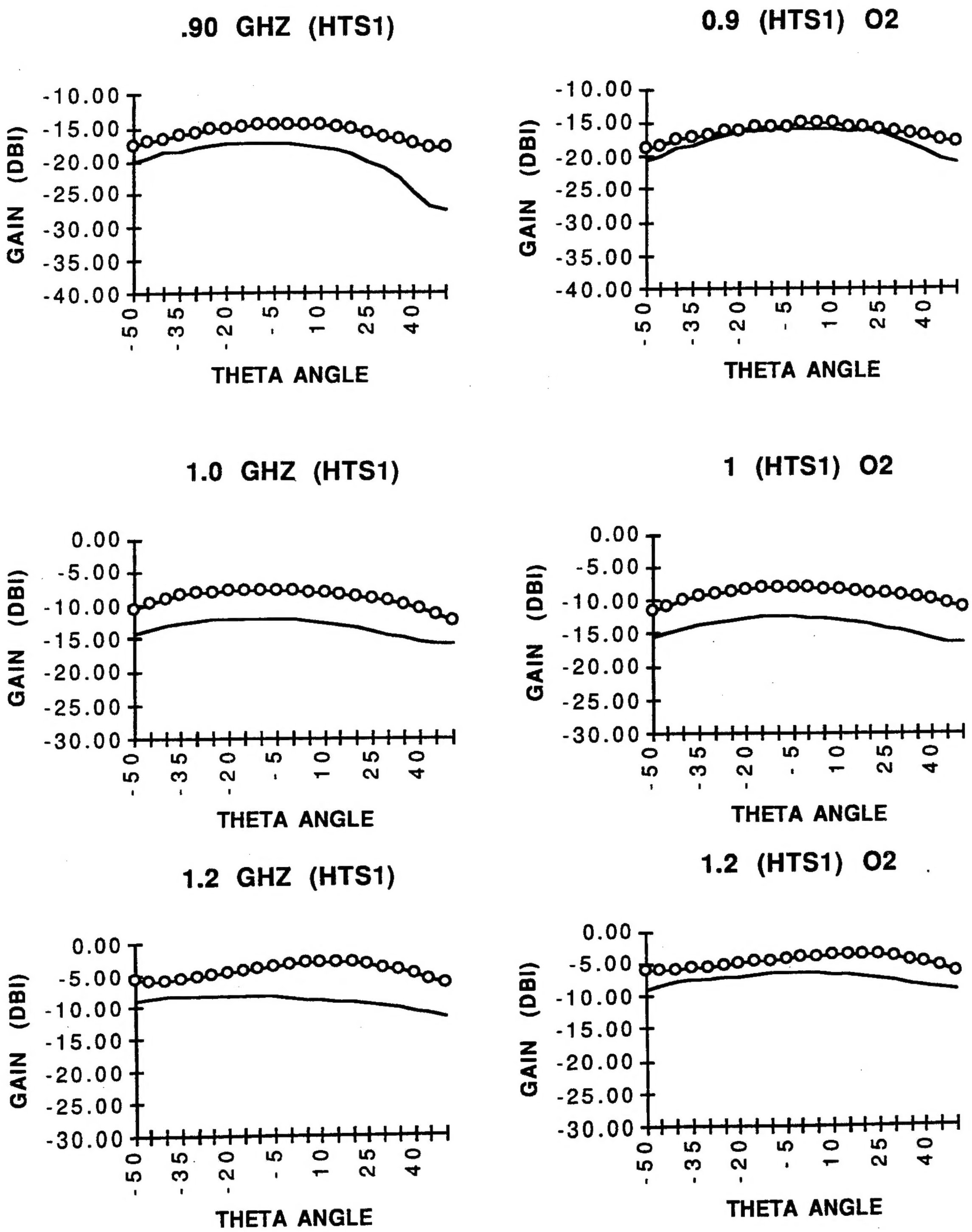


FIGURE D-2. (Contd.)

ORIENTATION 1 **ORIENTATION 2**

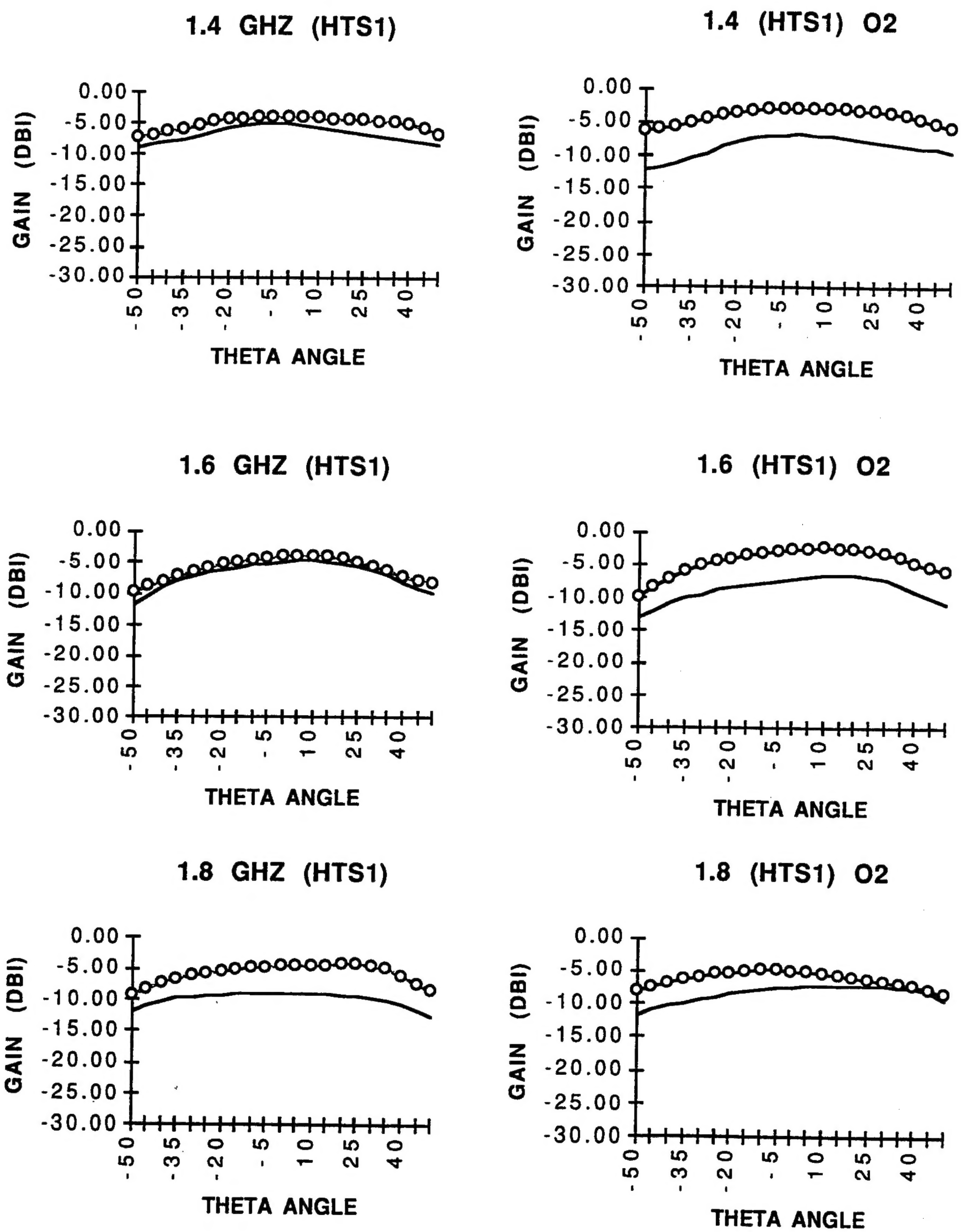


FIGURE D-2. (Contd.)

INITIAL DISTRIBUTION

1 Commander in Chief, U.S. Pacific Fleet, Pearl Harbor (Code 325)
1 Commander, Third Fleet
1 Commander, Seventh Fleet
1 Naval War College, Newport
1 HQ 497 IG/INT, Falls Church (OUWG Chairman)
2 Defense Technical Information Center, Alexandria
4 AEL Defense Core, Lansdale, PA
    F. Euehler (1)
    D. Martin (1)
    J. Schuehardt (1)
    G. Sou (1)
1 Center for Naval Analyses, Alexandria, VA (Technical Library)
1 Comarco, Incorporated, Ridgecrest, CA (D. White)
1 DuPont Central Research & Development, Wilmington, DE (Experimental Station)

ON-SITE DISTRIBUTION

1 Code 455560D, W. Katzenstein
1 Code 472000D, K. Higgins
3 Code 472230D
    T. Hoppus (1)
    D. Paolino (1)
    F. Schieffen (1)
15 Code 472310D
    C. Hauser (1)
    B. Joy (1)
    J. McCammon (1)
    M. Neel (10)
    D. Stapleton (1)
    D. Wagner (1)
3 Code 474160D
    D. Banks (1)
    D. Bowling (1)
    A. Martin (1)
1 Code 474180D, P. Overfelt
4 Code 474710D (3 plus Archives copy)